GEOLOGY OF DUBUQUE COUNTY.

BY

SAMUEL CALVIN AND H. F. BAIN.

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CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

From many standpoints Dubuque is one of the most important counties in Iowa. It was one of the first to be settled, and in the present connection it is to be noted that the early settlers were attracted to it by the mineral wealth of the region. It is to-day one of the richest counties in the state and includes the second largest city. To the geologist the region is of exceptional interest in that it includes portions of the driftless area together with deposits derived from three ice sheets of very different ages. The indurated rocks include an important portion of the Ordovician and Silurian section and are particularly well exposed. The history told by the physiography of the region touches many of the vital points of the recent geology of the interior. To the mining engineer the county offers a considerable variety of deposits. It offers also an opportunity to study the genesis of ores and the methods of their exploitation under exceptionally simple conditions. Lead, zinc, iron, clay goods, lime, building stone and artesian water are all produced, and copper, barytes, ochre, and cement rock occur. The presence of the river, with one north-south and two east-west railways, makes transportation cheap and affords opportunity for the economical development of the agricutural and mineral wealth of the region. The nearness of the mines to important smelting centers, to the coal fields and to the leading markets, afford an exceptional chance for the development of mineral properties.

In area, Dubuque county includes 601 square miles and is divided into eighteen civil townships as shown on the accompanying map. The eastern and a portion of the northern border of the county is formed by the Mississippi river, which separates it from Wisconsin and Illinois, the dividing line between which cuts the river opposite the city of Dubuque. South of Dubuque county lie Jackson and Jones, while to the west is Delaware and to the north is Clayton.

PREVIOUS GEOLOGICAL WORK.

The presence of important ore deposits in the region early attracted attention to it, and, as is detailed elsewhere, many geologists have visited the region. In a general way it may be said that there was, first, a period of discovery and exploration running from 1750 to 1838; second, a period of early geological work from 1839 to about 1860; third, a period of later geological work from 1870 to 1880; and fourth, a period of recent investigation from 1890 to date. To the first period belong the expeditions of Le Seuer, Pike, Schoolcraft, Nicollet and Featherstonhaugh. These did little except exploratory work and left no geological notes of permanent value. To the second period belong the researches of Owen, Percival, Hall and Whitney, with their assistants. In this period the area was defined, the formations differentiated and the correct theory of the genesis of the ores first foreshadowed. To the third period belong the activities of the second Wisconsin survey, with the work especially of Strong and Chamberlin. This was the beginning of detailed work in the region. To the last period belong the numerous recent studies of the region, made especially with a view to the deposits of zinc, and as a result of the recent increasing use of that metal. In another place in this report the separate papers of the various individuals who have visited the region are noted, and the development of the knowledge of the geology of the region and of the ore deposits is discussed.

PHYSIOGRAPHY.

TOPOGRAPHY.

The topography of Dubuque county may conveniently be considered under three heads, (1) the topography of the driftless area, (2) the topography of the loess-Kansan area, and (3) the topography of the Iowan areas. Under each of the three divisions of the topic many minor divisions might be made. The most striking topographic forms of the county are those of the driftless area, for the boundaries of which the reader is referred to the accompanying Pleistocene map. Within this area the surface inequalities are much greater than elsewhere. Here is a land of deep river valleys cut in the indurated rocks, a land of gorges associated with picturesque bluffs, a land characterized by prominent crags, isolated towers and steep rocky cliffs. With the exception of some conspicuous terraces and ridges of sand and gravel belonging to late Wisconsin age, all the prominent topographic features of the region have been developed by erosion acting upon rocks of varying degrees of hardness. The channel of the Mississippi, one of the dominating and most important topographic features of this whole region, is walled in by bluffs which rise to a height of 300 feet, and from the summit of the bluffs the surface slopes more gradually in places to a height of 200 or 300 feet more. The difference in elevation between the Peru bottoms and the top of Sherrill mound, for example, is about 600 feet. The Little Maquoketa, which, in Dubuque county, is the largest tributary of the Mississippi, in the central part of Center township flows in a valley 400 feet in depth. As is general in areas in which the surface features have been developed by erosion, the drainage courses divide and re-divide until the whole face of the country is marked by a dendritic system of channels which terminate on the slopes of the main divides in countless, minute, shallow trenches. (Fig. 45.) Between the ultimate branches of the drainage system the surface takes the form of rounded swells or ridges, but these may be much modified in their curves and outlines by the nature of the materials in which the trenches have been carved. For the topography of the driftless area, while developed by erosion, is modified and controlled to a very large extent by the hardness of the indurated rocks, so much so that each geological formation expresses itself in some form or other, in the characteristics of the surface. Along the whole river front from Waupeton to the southeast corner of Mosalem township, the Galena-Trenton formation gives rise to steep scarps and vertical cliffs which become more pronounced as the dolomitized Galena makes up more of their entire height. Precipices rising sheer for some scores of feet are common features of the landscape wherever erosion has cut into the Galena limestone. Examples of such cliffs are numerous, but those fronting the river near the southeast corner of Julien township, others at the mouth of Catfish creek, and many along the sides of the valley of the Little Maquoketa southwest of Durango will serve as types. The towers (Fig. 46) and castles so common in the eastern part of the county, are topographic features dependent on the manner in which the Galena limestone yields to erosion. Other features produced by unequal waste of this limestone are found in long, narrow, steepsided ridges, eighty to 150 feet in height, blending into the upland plain at one end, and running out in picturesque isolation at the other. They are produced by two nearly parallel erosion channels meeting at a small angle. Such a prominent salient is seen east of the junction of Valley street with Southern avenue, in the lower part of the city of Dubuque. An isolated knob of Galena limestone, 170 feet in height, cut off by the shifting of the channel of Catfish creek, and lying between the mouth of the creek and the valley here followed by the Illinois Central railroad, is one of the interesting phenomena connected with the development of the topography of the driftless area. On this prominent hill of circumdenudation stands the chaste and appropriate monument recently erected over the grave of Julien Dubuque.

No more charming and picturesque spot could possibly be found anywhere. The view from this lofty point commands the river for a number of miles in both directions. The great stream, placid and reposeful when undisturbed by river craft, and dotted with green islands away to the southern horizon, flows with seemingly conscious majesty past the very foot of the rocky cliffs forming the riverward face of the hill. In the middle distance to the eastward is the Illinois flood plain, threaded with channels carrying thin strands of water, and sprinkled with clumps of foliage trees which are richly luxuriant in the vivid greens of spring and early summer, and resplendent with flame and golden tints in autumn. Beyond the flood plain rise the eastern bluffs, and far away on the horizon stands Sinsinewa. Near the grave grows the wild grape vine, perfuming the air in spring, while overhanging oak and linn lend glory to the fall. The wild verbena blooms profusely through the summer season, and the hum of visiting bees makes an indefinite, unobtrusive, restful music, scarcely noticed amid the multitude of impressions which fill the mind of the visitor to this interesting spot with such peculiar delight. On warm summer afternoons the cool shades of the near-by forests ring with the rich, unmatched, melodious piping of the wood thrush, and one might easily fancy that the seclusion which brooded over the hills a full century ago had never been broken. And yet when attention is aroused the rest and seeming seclusion of this charming place is invaded from the north by the jar and mingled discord of all the sounds incident to the commerce and manufactures of a great modern city. If attention be given to the immediate surroundings only, the monument stands in the midst of unaffected nature. The sights and sounds are those which characterized the region at the first visit of the first white man more than a century ago. But within sight and hearing from the crest of the hill has grown up a city which perpetuates the name of the first miner who systematically worked the crevices of the Galena limestone for ores of lead. Much of the interest and picturesque charm of the locality depend on topographic features made possible only by the characteristics of the Galena limestone. Blocks of Galena limestone form the graceful monument beneath which he sleeps. Could more appropriate surroundings be chosen for the last resting place of Julien Dubuque?

The Maquoketa shales overlying the Galena, which will be discussed under the head of stratigraphy, are soft, easily eroded, and give rise to a very characteristic topography. In the region occupied by the shales the land forms are not so rugged and angular as those formed by the Galena, the curves are more flattened and regularly rounded, the slopes are more gentle. (Fig. 50.) The surface of the Maquoketa area is not developed into a plain; it is far from having a uniform slope; toward the west where the Maquoketa area joins the Niagara the surface may rise at a relatively high angle; toward the eastern edge of this area, the surface, as a whole, shows a tendency to become more horizontal. Furthermore, the summits of the minor ridges, even when a very limited area is considered, do not all rise to the same altitude. There is a certain tumultuousness and irregularity about the surface, even of those areas where there is, on the whole, a tendency toward a general leveling, which clearly distinguishes the region dominated by the shales from that of the loess-Kansan, where the surface features are somewhat similar, but developed by comparatively recent erosion in a sheet of loose drift. Except in the immediate neighborhood of the drainage courses, the surface of the Maquoketa area is level enough to admit of cultivation.

The Maquoketa shales are overlain by the hard magnesian limestone called the Niagara. The influence of the Niagara limestone on the topography of the county is even more marked than that of the Galena-Trenton. It is masses of Niagara limestone which form Sherrill mound and other smaller mounds in the same neighborhood. Table mound is the end of a narrow ridge reaching out like a promontory or rocky headland from the general Niagara area. Table mound is in fact a part of what, looking from the east, seems to be a continuous line of hills setting off the imperfect plain which begins at the summit of the Mississippi bluffs, from the higher table land occupying all the rest of the county to the westward. The hills are simply a line of steep slopes, sixty to a hundred and fifty feet in height, coincident with the eastern outcropping edge of a heavy body of Niagara limestone. This line of hills, very appropriately, has been called by McGee the Niagara escarpment. Traced on the ground it is found to wind back and forth to form the rims of sinuous, branching valleys, running back into the interior of the county for many miles, and projecting in digit-like extensions toward the larger valleys on the summits of the primary and secondary divides. Altogether it forms one of the most striking and one of the most generally recognized topographic features in the entire state of Iowa. It marks the present position of the edge of the Niagara limestone, but its position is not constant. Owing to continual waste under the effects of weather, the escarpment is slowly receding, and the area eastward to the river, and that east of the river to corresponding mounds and escarpments in Wisconsin and Illinois, are simply a measure of the extent to which the Niagara limestone has been removed from the surface by the erosion of the gorge of the Mississippi and its tributary valleys. Only the forms developed in the deeply gashed and eroded edge of the Niagara limestone are to be included in the topography of the driftless area; for while the margin of the loess-Kansan area does not coincide with the Niagara escarpment, the Kansan drift plain, with its special topographic types, does begin not very far to the westward.

Among the many interesting topographic features of the driftless area, there is none more striking than the Couler valley, a deserted river channel some five miles long, connecting the Little Maquoketa valley at Sageville with the Mississippi at Dubuque. This valley is a sharp walled canyon nearly 200 feet deep and about a half mile wide, with flat alluvial bottom. The northern portion is used by a small branch flowing into the Maquoketa, while Couler creek flows down the valley and through Dubuque to the Mississippi. There is no col and no divide proper. The valley is open and drains both ways. In time of very high water the Maquoketa still uses it for a portion of its flood. For example, in 1853 water passed through the valley, and at present its proper drainage forms a considerable problem. Couler valley connects with the Maquoketa valley a little more than a mile above the point where the latter opens out on the Mississippi bottom lands. The waters of the Maquoketa find their way into the Mississippi by traveling about two miles northeast from Sageville. By following the Couler valley they might, in five miles, find their way into the Mississippi some seven miles below the point at which they actually join it. They travel by a route which is, roughly, four miles longer than the one which has been deserted. The change has thus resulted in lengthening the course of the stream, and also in so diverting the tributary as to cause it to join the main stream higher rather than lower. Such a change requires especial explanation.

So far as can be learned there is no obstruction in Couler valley to account for the diversion of the stream. Such wells as are on record show a deep filling of the valley here, the same as along the Mississippi. As the locality is far outside the limits of the glacial action, the change cannot be referred to the agency of ice. Though the valley is crossed nearly at right angles by the Eagle Point anticline, there is no evidence connecting the rise of the latter with the diversion of the stream. In short, the explanation seems to be in the ordinary process of stream capture. From Sageville to the Mississippi by the present route is a shorter distance than by the old one, so that assuming that the Mississippi were at the same level at the two exits, the new route would have much the steeper grade, and a stream working along it would have the advantage over one flowing through Couler valley, and would in time capture the Maquoketa. The Mississippi has so slight a fall that practically the above supposed set of conditions obtain, and while the present course of the waters is the longer one, the greater volume of water in that portion of the course made up by the Mississippi compensates for the added distance, and enables the river to hold to its new course.

It is probable, too, that the situation of the mouth of the Maquoketa at a point where the Mississippi, for a long time, evidently cut against its western bank, was an efficient factor in promoting the change. That the change was a slow one, and that the river probably shifted several times before settling to its present course, is indicated by the anomalous topography where Bloody Run joins the Maquoketa at Sageville. Bloody Run has evidently shifted its channel to the northeast to accommodate itself to the change in the course of the Maquoketa, and in the process it has abandoned the lower portion of its old channel. The cut used by the Chicago Great Western railway in passing from the Couler to the Maquoketa valley is a col, but it probably does not mark the former main channel. If, however, the Couler valley had continued to be used by the river the latter would, in time, have found its way through this gap.

Another interesting example of stream rearrangement is seen near the mouth of Catfish creek. A few hundred feet north of the present mouth is an old valley now used by the Illinois Central railway and connecting with Catfish valley about a half mile from the river. The stream has evidently shifted its course so as to empty into the Mississippi farther down the main channel. Possibly Grange creek formerly had independent outlet and has captured Catfish.

The date of the rearrangements of the streams is unknown. Apparently they are not recent, and certainly they are pre-Wisconsin, since the terrace gravels of the Wisconsin age occupy new and old valleys alike. If one may judge by the relative sharpness of the topograpy in the vicinity of the post-Kansan gorge of the Catfish, in Table Mound township, the changes just described are of preglacial age.

It will probably be sufficient here merely to note, as a feature of the topography of the driftless area, the ridges and terraces of Wisconsin gravels, which will be more fully described in a later part of this report under the head of deposits of the Pleistocene.

Leaving out the small lobes of Iowan, the loess-Kansan topography will be found well illustrated in all the remaining parts of the county lying inside the border of the Kansan drift. Where this topography is typically developed the surface is an undulating plain upon which a miniature erosional system of hills and trenches has been developed. The inequalities of the surface have, in general, been carved in the loose materials later described in this report as loess and Kansan drift. Evidences of rock cutting in connection with this phase of erosion are very rare. On the slopes adjacent to the larger drainage courses the water-cut trenches may be twenty, forty, or even sixty feet in depth, with the sides of the ravines steep and the curves all sharp; but there are certain large areas in which the loess-Kansan surface is gently undulating, the water courses being broad, shallow depressions, while the convex curves are low and flat. One of these areas, so far as it belongs to the loess-Kansan province, occupies the northern half of the entire south tier of townships, together with the southern half of Dodge, Taylor, Vernon and Table Mound. Another similar area embraces the western part of Iowa and Concord townships, all but the northwest corner of Liberty, and nearly all of New Wine. The boundaries indicated for these areas are only approximate, the object being simply to give concrete illustrations of a most important type of surface configuration. As fair an illustration, however, of the moderately undulating loess-Kansan plain as can be found anywhere occurs between Peosta and Epworth; while the whole of Washington township, except the southwest corner, and all of Prairie Creek, except the southeast corner, present the same general type of topography. The moderately eroded loess-Kansan plain, with its subdued relief, is perhaps the most important part of the county from an agricultural point of view. A dark, friable, loamy soil is here developed

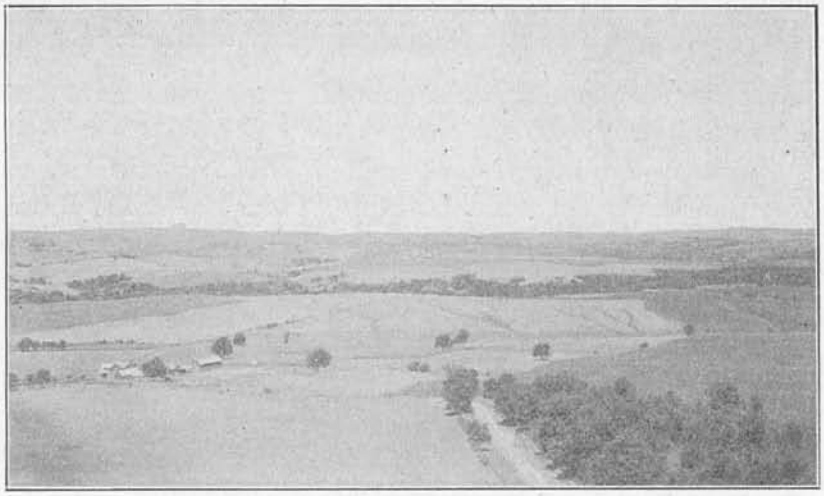


FIG. 45. Topography of the driftless area underlain by Maquoketa shales. View taken from top of Table Mound looking north.

on the loess, and farms of easy tilth and generous productiveness at once account for the evidences of comfort, plenty and general prosperity which everywhere abound among the fortunate occupants of such a region. The loess-Kansan area mapped in Dodge township is a somewhat prominent ridge overlooking two low lying lobes of Iowan drift.

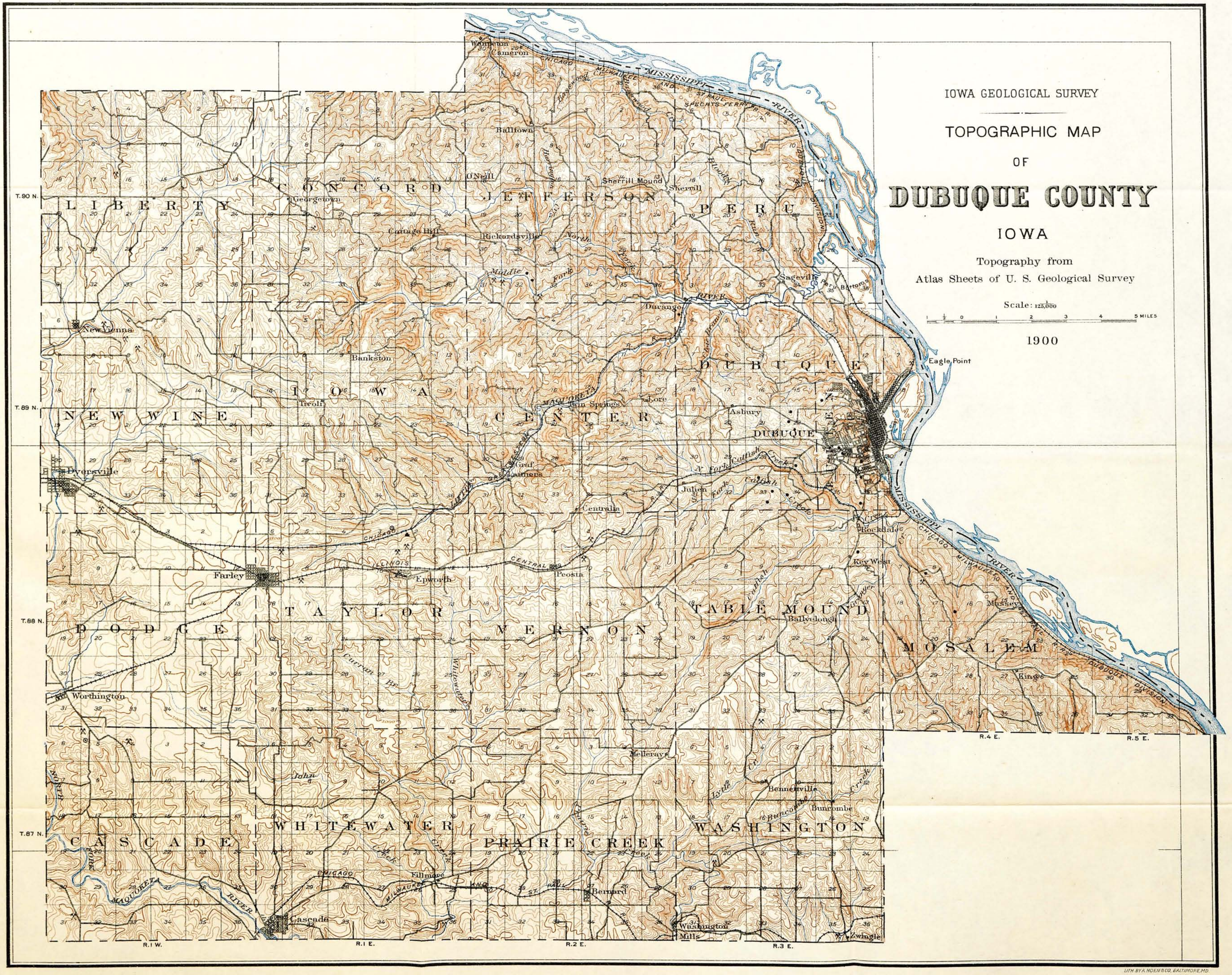
The topography of the Iowan lobes is very simple. In general the surface is flat. Whatever inequalities and irregularities it may possess are constructional and not erosional. It is not covered with loess, but is sprinkled with large granite bowlders. The drainage is not as perfect as in the loess-Kansan region. The soil is a very black, rather tenacious, very fertile loam. The level, bowlder-dotted plain upon which the Illinois Central railroad enters west of Farley affords a concrete illustration of the Iowan topography.

Between Dubuque and Peosta the traveler has on all sides the bold topographic forms of the driftless area; from Peosta to Epworth the surface presents the miniature erosional forms of the loess-covered Kansan plain; west of Farley the scene changes suddenly to the new, immature topographic features of the Iowan.

DRAINAGE.

Although the drainage of Dubuque county is controlled by the Mississippi river, the surface of the county is divisible into two main drainage areas which are separated by the rather indefinite ridge marking the border of the Kansan drift. On one side of this dividing line is a driftless area with waters recognizing at once the authority of the master stream and flowing directly towards it. The greater part of this area is covered by two drainage valleys—that of the Little Maquoketa and its many branches, and that drained by the several forks of Catfish creek. The other streams of the driftless area are small and of little importance. Hollow creek, in the northwest corner of Liberty township, may be mentioned in connection with the streams of the driftless area; in place of flowing directly toward the Mississippi river this stream flows into a tributary of the Turkey.

The western portion of the county embraces the drift-covered areas. Here the drainage courses, beginning in the marginal ridge of the Kansan drift, all trend at first toward the southwest, directly away from the Mississippi river. Lytle creek and Whitewater creek, in Washington and Prairie Creek townships, illustrate the general tendency west of the drift margin. These streams are tributary to the North Maquoketa, which, beginning in Liberty township with the southwest trend common to the drainage of this region, passes from Dubuque into Delaware county south of Dyersville, after which it changes its course to the southeast, traverses the southwest corner of Cascade township and receives the surplus waters from the southern portion of the drift-plains of



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the county. The Little Maquoketa has backed up so as to capture a small part of the drainage from the drift-covered area. Whatever the cause, it is true that the general trend of the drainage in the two principal areas is in directly opposite directions, and approximately at right angles to the drift margin.

STRATIGRAPHY.

GENERAL RELATIONS OF STRATA.

The geological formations of Dubuque county are of unusual interest, and, compared with other counties in Iowa, they are more than the average in number. The deep erosion to which the driftless area, occupying the eastern part of the county, has been subjected has cut down through one formation after another, so as to give continuous vertical sections of three to four hundred feet in thickness. Satisfactory exposures are multiplied by the score in every gorge and valley of the driftless region; some of the most instructive being found almost in continuous sequence from one end of the county to the other, along the picturesque bluffs of the Mississippi river. On account of the great amount of rock erosion in the driftless area, and owing to the absence of the drift mantle which, over the greater part of Iowa, effectually conceals the indurated rocks, the geological structure of Dubuque county lies open to the observer in a way unknown in the drift-covered portions of the state. Excepting the valley of Hollow creek —Pine Hollow, as it is frequently called—in the northwest corner of Liberty township, the western part of the county is covered with drift; and since no deep valleys have been excavated since the deposition of the drift, the comparatively few rock exposures of this region all belong to a single formation.

The general relations of the geological strata of Dubuque county are expressed in the following synoptical table. In studying the table, however, the reader will please bear in mind that while some of the names in the last column are names of recognized geological stages, the authors have taken the liberty, especially in the Pleistocene, to use formational names having neither uniform nor co-ordinate taxonomic value.

SYNOPTICAL TABLE

SHOWING TAXONOMIC RELATIONS OF GEOLOGICAL FORMATIONS IN DUBUQUE COUNTY.

GROUP.	SYSTEM.	SERIES.	FORMATION.
Cenozoic.	Pleistocene or Quaternary.	Recent.	Alluvium.
		Glacial.	Wisconsin Terraces.
			Iowan Drift.
			Loess
			Buchanan Gravels.
			Kansan Drift.
			Residual Products.
Paleozoic.	Silurian.	Niagara.	Delaware.
	Ordovician.	Trenton.	Maquoketa.
			Galena.
			Trenton.
		Canadian.	Saint Peter.

So far as known there are but two systems of indurated rocks, the Ordovician and the Silurian, represented in Dubuque county. The Rockville conglomerate, provisionally referred to the Cretaceous system by McGee,* occurs in Delaware county, near Rockville, within three-fourths of a mile of the Dubuque county line; but no exposures of this formation were observed in the county now under consideration. The conglomerate, where known, occurs in small, detached patches which might very easily be overlooked.

*Pleistocene History of Northeastern Iowa, by W J McGee; Eleventh An. Rept. U. S. Geol. Surv., pp. 234, 307, 308. See also Report on Delaware county, by Samuel Calvin; Rept. of Iowa Geol. Surv., Vol. VIII, pp. 160, 161.

On Table mound, and possibly on other high points in the county, are traces of a gravel corresponding in all essential particulars to that described by Professor Salisbury from the Devil's Lake region of Wisconsin.† This gravel consists of chert and quartzose material, thoroughly rounded, and, while the relations are not thoroughly clear, it seems best to refer it to pre-glacial agencies. In its presence here and on Iron Hill, near Waukon,‡ it shows a habit similar to that observed in Wisconsin. That it is found on the high points only seems to indicate a former extension over the whole region at a period anterior to the valley cutting. Its age cannot be more definitely asserted until a fuller study of the gravels of the whole region shall have been made. Such a study would doubtless clear up much of the pre-Pleistocene history of the region and allow the drawing of some inferences of value as to the age of the drainage.

From both the commercial and the scientific point of view the beds in this county belonging to the Ordovician are more important than those belonging to the Silurian. The Ordovician formations are found in the eastern part of the county, in the area of deep rock erosion, in the area where the drift mantle was not deposited, the area where the indurated rocks are not concealed, except so far as they are hidden by the thin and frequently interrupted accumulation of loess and residual clays. By far the greater number of the rock exposures in the county, therefore, belong to one or the other of the Ordovician series. The Ordovician presents a larger number of distinct formations than the Silurian, and a correspondingly larger number of interesting geological problems; while the single formation known to geologists as the Galena limestone, with its unexcelled material for lime burning, its quarry products suitable for massive and other forms of masonry, and its immense deposits of the ores of lead and zinc, and occasional beds of iron, gives to the Ordovician a commercial importance unapproached by any other system in

‡I-,wa Geol. Survey, Vol. IV, p. 85.
†Jour. Geol., Vol. III, pp. 655-667.

Iowa, except the Carboniferous. The other Ordovician formations are not devoid of interest from any point of view.

ORDOVICIAN SYSTEM.

SAINT PETER SANDSTONE.

The oldest geological formation found in Dubuque county is the Saint Peter sandstone. It is exposed at a number of points along the Mississippi bluffs, from a mile or two above Specht Ferry to Zollicoffer lake, a distance of five or six miles. The strata forming the section seen in these bluffs are thrown into a series of gentle folds which cause the sandstone in places to appear above the railway track that here follows the river, and in places to dip below it. At Specht Ferry the top of the Saint Peter is seen near the railway station and nearly on a level with its platform. Three-fourths of a mile above the station a small syncline depresses the top of the sandstone ten feet below the level of the track, while one-fourth of a mile farther up the river the sandstone ascends a few feet above the bed of the railway. Maintaining this level for some distance, it again descends, and is not afterward seen in this direction in Dubuque county.

From one-half to three-fourths of a mile below Specht Station there are good exposures of the Saint Peter, showing the upper five feet of the formation above the bed of the railroad, and from twenty-five to thirty feet above the level of the river. The sandstone is here somewhat definitely bedded, being divided into a few comparatively thin ledges. Farther north, in Clayton and Allamakee counties, where this formation is exposed throughout its whole thickness, bedding planes are few; indeed in places it would seem as if the sand had been deposited continuously so as to form one undivided stratum. The sandstone appears at intervals in following down the river, the points of appearance coinciding with the axes of anticlinal folds. The last appearance noticed was opposite the middle of Zollicoffer lake, where a single undivided ledge, six feet in thickness, rises above the grade of the railway.

The Saint Peter sandstone, as seen in Dubuque county, is rather ferruginous, and it is very generally stained in varying shades of red and brown and yellow. The colors are dull and dingy, as a rule, in marked contrast with the clean, clear whites and the bright reds and other tones which lend such pleasing variety to sections of this formation when the main body of it is exposed. The coloration of this sandstone in Dubuque county is due to infiltration from above, as the overlying Trenton limestone is wasted by the solvent action of air and water, and contributes its contained iron, in oxidized condition, to discolor the pure, white quartz sand which normally makes up the Saint Peter formation. Owing to its greater insolubility the Saint Peter recedes in bluffs and hillsides more slowly than the Trenton, so that it is common to find a bench or terrace of the sandstone projecting beyond the foot of the cliffs of limestone. It is the upper layers of this bench that are discolored by the descending waters which carry various waste products of the limestone in solution.

As to texture, the sandstone is coarse; it is more or less friable. In the normal condition, as seen where it is more completely exposed, the sand grains have about as little cohesion as when they were originally laid down in the Ordovician seas. The upper five or six feet—the only part of the natural exposures of this formation in Dubuque county left unconcealed by railway embankments and talus slopes—have been cemented to a greater or less degree by the iron and calcareous salts carried from the overlying limestone and deposited from solution in the interstitial spaces of the sandstone. The resulting consolidation has made it possible, in some cases, to use the Saint Peter as quarry stone. At Specht Ferry there is a large, two-story building, eighty by thirty feet on the ground, constructed of blocks quarried from this formation and bearing evidence of the skill of the professional stone-cutter. So far as known to the writers this is the most pretentious structure in Iowa made from the Saint Peter sandstone.

In this county the Saint Peter sandstone contains no organic remains. At all events, no fossils were observed. The formation is very generally unfossiliferous. The conditions under which such a bed of sandstone could accumulate would make life on the sea bottom well nigh impossible; but even if the seas of the age had swarmed with life, it is extremely improbable that any traces of it would be preserved. For what is known of the fauna of the Saint Peter sandstone the reader is referred to Volume IV of the present series of reports, pages 72 and 73.

TRENTON LIMESTONE.

The Saint Peter sandstone is followed, apparently conformably so far as this county is concerned, by the formation generally recognized in the west as the Trenton limestone. Hall, in his report on the geology of Iowa, published in 1858, seems to have been the first geologist dealing specifically with Iowa geology, to correlate the strata occupying this horizon with the Trenton limestone of New York. In 1843 Conrad, in the proceedings of the Academy of Natural Science, Philadelphia, published descriptions of fossils found at Mineral Point, Wisconsin, and recognized the fact that they were associated with a fauna characteristic of the New York Trenton. In the first volume of the Paleontology of New York, published in 1847, Hall redescribed Conrad's species, and noted the fact that they occur in blue limestone associated with Trenton limestone fossils. In the earlier report of Owen, published in 1844, and giving an account of geological explorations made in Iowa, Wisconsin and Illinois in the autumn of the year 1839, this formation is named, in figures 5, 6 and 7 of Plate I, the *Blue fossiliferous limestone;* while in his later report on the geology of Wisconsin, Iowa and Minnesota, published in 1852, Owen describes the formation following the Saint Peter sandstone under the title of the *Saint Peter's Shell limestone.* Hall's example has been very generally followed by later geologists. At all events, some beds immediately overlying the Saint Peter sandstone have been referred to the Trenton by all subsequent writers on western geology when discussing this part of the geological column; but there has been a conspicuous lack of agreement amongst the several writers as to the precise upper limit of the formation in question. Some of the discordant conclusions respecting this subject have evidently arisen from the fact that the problem has generally been approached with what now seems to be an erroneous preconception. It was at first assumed, and quite naturally, too, that the Trenton and Galena limestones are two distinct formations, sharply set off one from the other by a definite plane, or at least by transition beds occupying a definite horizon. In making discriminations between the two formations it was taken for granted that the Trenton is, as a rule, thin bedded and non-dolomitic, while the Galena is made up of heavy, massive beds, and is uniformly and completely dolomitized. As illustrations of the varying conclusions which have been reached respecting the thickness of the Trenton,—how far above the Saint Peter sandstone the line separating the Trenton from the Galena should be drawn—the following references are instructive. Hall,* in his report on the Geology of Iowa, gives the thickness of the Trenton at Pike's Hill as seventy-five feet, and that without including the "magnesian beds below" (Lower buff beds) in the estimate; at Elkader he makes the thickness twenty-five feet; near Clayton City he reports a thickness of twenty to thirty feet; and in rear of the town of Guttenberg he gives a thickness of 100 feet to the strata between the top of the Saint Peter and the base of the Galena. White,† writing of the Trenton limestone, says: "The thickness of this formation as seen along

*Geological Survey of Iowa, by James Hall, 1858, Vol. I, Part I, pp. 54-59.
†Geological Survey of Iowa, by Charles A. White, 1870, Vol. I, p. 175.

the bluffs of the Mississippi is about eighty feet, but in Winneshiek county we find the thickness increased to upwards of 200 feet." Both Hall and White treat the Galena limestone as an independent formation having definite characteristics, vertical dimensions, and geological position of its own. In the reports of the Geological Survey of Illinois, conducted by Worthen, there are references in Volumes I, V and VII to the Trenton limestone as it occurs in parts of the state adjacent to Iowa. The Galena and Trenton are usually treated together under the name of the Trenton group, the intimate relations of the two formations being thus recognized; but it is still assumed, though not expressly stated, that the lead-bearing Galena is separated by a definite formational plane from the blue and buff divisions, which are usually correlated with the New York Trenton. Worthen divides his Trenton group into three divisions, as follows:

	FEET.
Galena, or lead-bearing limestone	250 to 300
Thin bedded, bluish-gray limestone (glass rock in part)	50 to 75
Buff and brown magnesian limestone	20 to 30*

Under the name of the Trenton group Chamberlain † very properly combines the Trenton and Galena limestones and the Cincinnati (Maquoketa) shales. The Trenton and Galena are treated separately, and the Trenton is divided into four members, as follows:

	FEET.
Upper blue beds	15
Upper buff beds	55
Lower blue beds	25
Lower buff beds	25

This gives 120 feet between the top of the Saint Peter sandstone and the base of the recognized Galena. Worthen measures 100 feet of strata between the same limits. White recognizes a variation of from 80 to more than 200 feet, and Hall's measurements of the beds belonging to this position range

*Geological Survey of Illinois, Vol. I, 1866, p. 141.

†Geology of Wisconsin, survey of 1873-1877, Vol. II, p. 290 *et seq*.

from 20 to 100 feet. In the fourth volume of the present series of reports of the Iowa Geological Survey, in the report on Allamakee county, Calvin estimates that there is something more than 250 feet of limestones and shales between the Saint Peter sandstone and the dolomitized Galena. McGee's description of the Trenton of Iowa* embraces the following statement: "The richly fossiliferous limestones of this formation are moderately pure, heavily bedded, and nearly free from argillaceous matter in the southernmost exposures, where the mass is perhaps seventy-five feet in thickness; but northwestward the body thickens rapidly and becomes shaly, particularly in its upper portion—its thickness in northern Winneshiek county reaching not less than 250 and perhaps 350 feet." On the other hand N. H. Winchell limits the application of the term Trenton limestone to the calcareous beds lying between the Saint Peter and the horizon of green shales which seem to occur everywhere in the Mississippi valley not very far above the base of the Trenton. In Allamakee and Dubuque counties, where these formations have been most carefully studied in Iowa, the green shales of the Minnesota geologists are found from forty to fifty feet above the top of the Saint Peter sandstone. The beds intervening between the Saint Peter and the green shales must be thinner in Minnesota; for Winchell, describing the Trenton of Houston county, says:† "This formation, as known in Houston county, consists of limestone layers that amount to a thickness of not more than fifteen feet. These layers are overlain by beds of shale and fossiliferous shaly limestone which reach an unascertained thickness, but probably not exceeding twenty-five feet. These shaly beds have been denominated "Green shales" in the reports of progress of the survey, but they seem to belong to the Hudson river age of New York. They are overlain in Fillmore county, and in northeastern Iowa, by firm calcareous strata which attain a thickness of fifty or

*Pleistocene History of Northeastern Iowa; Eleventh An. Rept. U. S Geol. Surv., p. 329. Washington. 1891.

†The Geology of Minnesota, Vol. I, of the Final Report, p. 218, 1884.

sixty feet, which seem to fade into the Galena formation of Iowa." In the report on Fillmore county* the "green shales" are assumed to belong to the Hudson River group of New York, and the further statement is made that "if any designation besides Hudson River be needed, the term Galena may include all the calcareous strata above the green shales belonging to the Lower Silurian."

Later, however, as a result of careful paleontological studies, Winchell was led to modify the view he had entertained respecting the position of the "green shales" and the overlying calcareous strata which he had correlated with the Galena, the view,—namely, that "there is reason to include them all in the Hudson River epoch."* In his paper† on the age of the Galena limestone, in the *American Geologist* for January, 1895, he concludes, after an exhaustive examination and analysis of the faunas of the formations under consideration, that there is a close alliance of the Galena with the Trenton; that the Galena changes gradually to the north by acquiring shale; that paleontologically it has no downward limitation; that in fact the Galena is only a phase of the Trenton, intensified in the typical region, and fading out in all directions; and that the physical break and the faunal change which follow it, in the northwest, are the probable parallels of those which mark the transition from the Trenton to the Hudson river.

Norton, in his memoir on the artesian wells of Iowa,‡ expresses the view, suggested by an examination of well records, and tentatively entertained by members of this Survey on the basis of studies in the field, that the difference between the Galena and Lower Trenton is merely lithological and not formational. He regards it as very probable that the strata included under the names of Galena and Trenton are one formation which varies locally in the extent to which dol-

*Op. cit., pp. 289 and 293.

*Op. cit., p. 289.

†American Geologist, Vol. XV, p. 33. Minneapolis, 1895.

‡Artesian Wells of Iowa, by William Harmon Norton, Rept. Iowa Geol. Sur., Vol. VI, p. 146. Des Moines, 1897. See also Plate vi, opposite page 139.

omitization has taken place; and this single formation he discusses under the name of Galena-Trenton. Further study he thinks, however, is desirable, and he says: "To demonstrate their formational identity it will be necessary to trace through both the same life zones, and this may be left in confidence to future work in the field."

The above references, showing estimates of thickness for the Trenton, as it was at first recognized, ranging all the way from fifteen to 350 feet, and the later tendency to unite the so-called Trenton and Galena under one formational name, sufficiently illustrate the discordant views which have been held and expressed respecting the limits to be assigned to the Trenton limestone and the significance which should be attached to the term, as the formation is developed in the valley of the Mississippi river. It may not be possible to reconcile all these differences of opinion, though it would not be difficult to point out how, in the most natural way, they have originated. Some facts developed by later studies of the Galena-Trenton of Iowa confirm the opinion that the two supposed formations, at least as these formations have been recognized by the geologists of Iowa, Wisconsin, and Illinois, constitute one geological unit. This unit varies somewhat in thickness in different localities; it varies locally as to the amount of argillaceous matter which it contains; but its chief variation, and that which more than anything else has led to the discrepant opinions that have just been noted, lies in the extent to which it has been altered by the process of dolomitization. It may safely be assumed that, aside from the shaly portions, the material originally composing the formation was calcium carbonate derived from the disintegration organic skeletons; and that in certain parts of the geologic basin the calcareous beds, or some limited portions of them, were altered to dolomites. The process of dolomitization was more complete in some portions of the basin than in others, and affected the strata through a much greater thickness. As a result of the alteration, bedding planes were obliterated where the layers were not separated by bands of shale, and thus the massive ledges which we now recognize as characteristic of the Galena, were produced. Traces of fossils were, to a very large extent, blotted out; this being particularly true of brachiopod shells and other forms which blended homogeneously with the matrix. In Iowa, Wisconsin, and Illinois the dolomitized portion of the formation has been called the Galena limestone; while most geologists have been calling the non-dolomitized portion, no matter what its thickness or what life zones it may happen to embrace, the Trenton.

The alteration of the original limestone was more complete, and descended further toward the bottom of the formation in the vicinity of Dubuque than anywhere else in Iowa. Accordingly it is at Dubuque that the Galena limestone part of the formation is thicker, and the typical Trenton correspondingly thinner, than in such localities as Winneshiek and Allamakee. In the counties last named dolomitization affected comparatively few layers, and these are in the upper part of the formation; the greater part remains but little or not at all changed, and hence the surprising thickness of the so-called Trenton reported from this part of the state.

In support of the view that the Galena-Trenton represents but a single formation which has suffered more alteration in certain localities than in others, the following facts are noted: The combined thickness of the two alleged formations remains nearly constant. Where the Trenton limestone is greatly thickened, as in the northern part of the state, the Galena limestone is thin; while at Dubuque the great thickening of the Galena is accompanied by the greatest attenuation of the Trenton. The "green shales" of the Minnesota geologists constitute a well marked and constant horizon, characterized by a distinct fauna, of which *Orthis* (*Dalmanella*) *subæquata* Conrad, and *Orthis tricenaria* Conrad, are diagnostic species. At all events, if these two species of Orthis are not strictly limited to the green shales, their range is confined to a very narrow zone in this part of the geological column. In Iowa the bed of shales containing the species named lies practically parallel with the base of the Trenton, between forty and fifty feet above the top of the Saint Peter sandstone. Now, in Allamakee and Winneshiek counties the dolomitized Galena begins more than 200 feet above the *Orthis subæquata* horizon; while at the Eagle Point Lime Works, in Dubuque, heavy bedded dolomite (Galena) begins directly on top of the green shales, carrying *O. subæquata*, *O. tricenaria* and associated species of the green shales fauna, and not more than sixty or sixty-five feet above the upper surface of the Saint Peter sandstone, which rises to view about five miles up the river, at Zollicoffer lake. Some hundreds of feet of strata, which are non-dolomitic and have been referred to the Trenton in Allamakee and Winneshiek, are completely dolomitized and assigned to the Galena in Dubuque. There are well defined life zones in the so-called Trenton of the northern counties, which have their counterparts at the same distance above the Saint Peter in the Galena. For example, along the Yellow river, in Allamakee county, there is a zone, ten or fifteen feet in thickness, carrying a gastropod fauna which embraces *Maclurea bigsbyi* Hall, *Maclurina cuneata* Whitfield, *Murchisonia* (*Hormotoma?*) *bellicincta* Hall, *M.* (*H.?*) *major* H., *Fusispira elongata* H., and *F. inflata* Meek & Worthen. In the northern counties the beds carrying this fauna, and superincumbent beds to a thickness of seventy or seventy-five feet, have always been referred in Iowa to the Trenton; but this same fauna occurs in the Galena limestone at Dubuque, and its place in the geological column is the same as in Allamakee county, namely, from 200 to 220 feet above the base of the Trenton, or from 80 to 100 feet below the contact of the Galena with the overlying Maquoketa shales. Another life zone equally persistent and equally significant, is that of *Receptaculites oweni* Hall. This species has been supposed to be especially characteristic of the Galena. It ranges through 100 or 120 feet of the formation, but specimens are rare, except in a band about ten feet in thickness and sixty feet below the contact with the Maquoketa. This is the true Receptaculites zone. At this horizon the puzzling and curious disks are numerous and fairly crowded together. Furthermore, the horizon is constant and easily recognized throughout the Dubuque district. Studies outside the district, however, show that the same zone, characterized by the great development of this same species of Receptaculites, is found in the same geological relations in non-dolomitized beds which have been counted as typical Trenton. The Galena-Trenton is one formation which in some way, at present not well understood, has had the original calcareous beds changed to dolomite to a much greater extent and through a much greater thickness in some localities than in others. As above stated, the unchanged beds have been called Trenton, the dolomitic beds Galena; and the apparently irreconcilable statements concerning the thickness of the respective assumed formations have been due to the preconception that the whole of the Galena overlies the whole of the Trenton, with a definite formational or stratigraphic plane of separation between them. Instead, a large part of the Galena near Dubuque is the exact equivalent, bed for bed, of a correspondingly large part of the Trenton in northern Iowa. Bands characterized by distinct types of life, run parallel and continuously through dolomite in one place and unaltered limestone in another. The relations of the two formations are illustrated in Plate No. 2. The line of separation is not formational; it pays no regard to stratigraphic planes, except that in places it seems to be determined for some distance by beds of shale; it cuts across individual layers and life zones in the most erratic manner; and while, on the whole, it rises toward the north, it wanders up and down through many feet in very short space, as evidenced by the sections recorded by Hall near Elkader, Clayton City, and Guttenberg in Clayton county.

It looks as if dolomitization had affected the limestone and produced the Galena type after the formation was complete; that the process began at the top and progressed downwards;

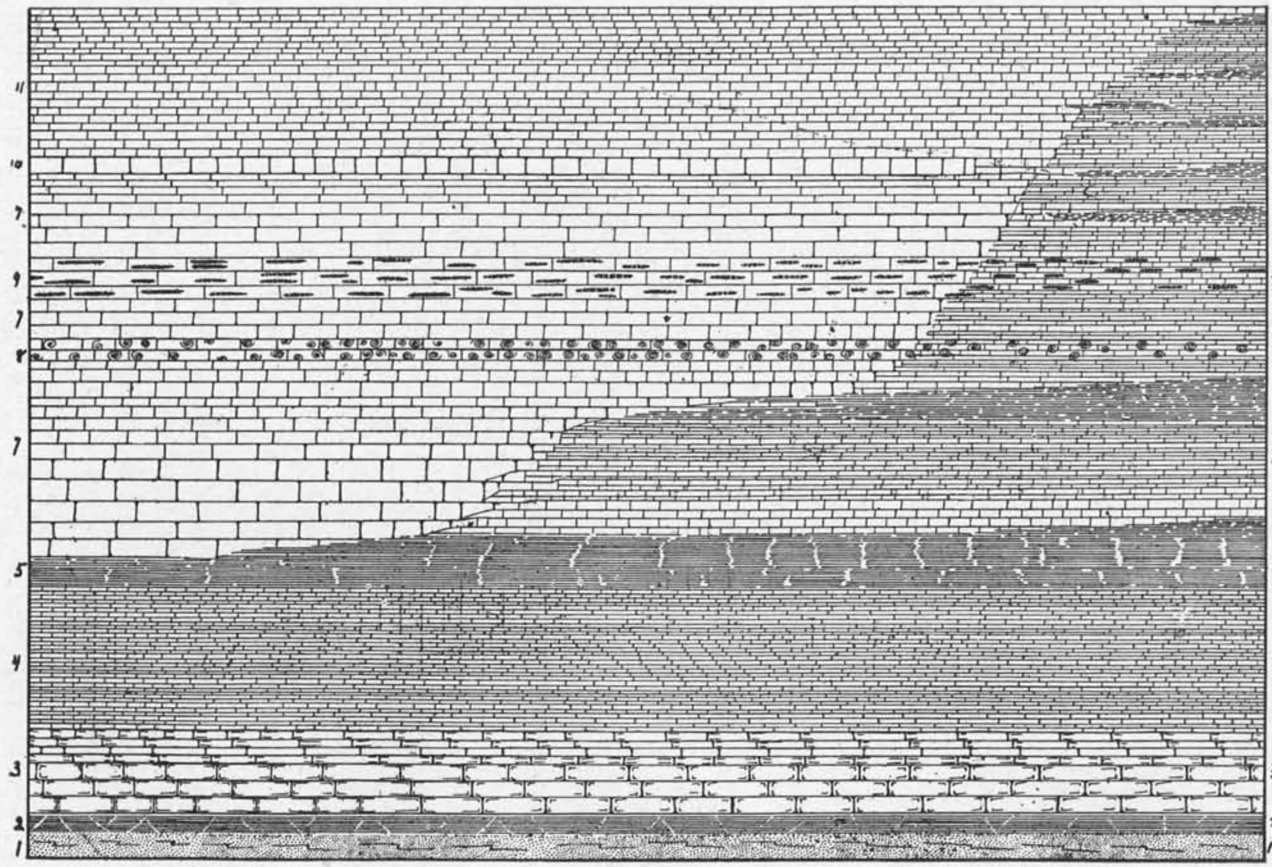

PLATE 4. General section showing the relations of the Galena-Trenton; the vertical scale very much exaggerated. 1. Saint Peter sandstone. 2. Basal shale. 3. Lower Buff beds. 4. Thin, non-magnesian beds equivalent to Nos. 3, 4 and 5 of the Specht Ferry section. 5. "Green shales," equal to No. 6 at Specht Ferry. 8. Gastropod horizon. 9. Receptaculites beds.

and that the depth to which the change descended was, in some instances and to some extent at least, determined by the presence or absence of impervious beds of shale. It has been already noted that at Eagle Point the Galena begins immediately above the "green shales" of Minnesota—the *Orthis subæquata* horizon. At Specht Ferry, ten miles up the river, there is a second shale bed separated from the green shales and their *subæquata* fauna by twenty-five feet of thin bedded, blue, fossiliferous limestone. In this locality the dolomitized Galena type of the formation begins above this upper shale bed, and so the beds which would ordinarily be referred to the Trenton, attain here a thickness of ninety-five feet in place of the sixty-five at the Eagle Point lime works. In Allamakee and Winneshiek counties the formation, as noted by McGee and others, becomes more argillaceous, especially toward the top, and the dolomitized portion which would be referred to the Galena, is limited to the comparatively few layers which overlie heavy beds of shale. Shale beds, while not necessarily the only factors, or even the most important ones, seem yet to have played an important role in controlling the depth to which the process of dolomitization was carried. If dolomitization in the present case was due to isolation of the Galena-Trenton basin, and concentration of the sea water which it contained, taking place after the beds composing the formation were all completed, it is easy to see how the descent of the process might effectually be stopped by beds of impervious shale. The conclusions of Winchell in 1895, and of Norton in 1897, appear now to be fully justified; and in considering the entire formation, as it is developed in Iowa, Wisconsin, and Illinois, geologists can do no better than to follow the example of Norton and call it the Galena-Trenton.

Geographical distribution.—The striking differences between the dolomitized and non-dolomitized parts of the formation make it convenient still to treat the two parts separately; and if the facts presented above are kept in mind, no confusion will arise from following previous custom and discussing one portion under the name of Trenton and the other under that of Galena. With the understanding that the term has no formational significance, it may be said that the Trenton limestone is exposed along the bluffs of the Mississippi from Waupeton to Eagle Point. So far as this county is concerned, its outcrops are almost wholly limited to the bluffs fronting the river; it is never seen very far back in the interior of the county. With the exception of the Little Maquoketa, all the tributary streams joining the river between the point where the Mississippi first touches the border of the county and the point where the Trenton finally dips out of sight in the northern part of the city of Dubuque, are small, and the valleys or ravines which they follow have steep gradients. Accordingly in following each of these several ravines back from the mouth, it is found that the bottom rises above the level of the Trenton in a fraction of a mile; in most cases, indeed, within a very few rods. It is only along the Little Maquoketa that the Trenton is found at any considerable distance back from the Mississippi, and even here the exposures of this formation can not be traced very far up the valley, the last observed outcrops in this direction being scarcely more than three miles from the eastern border of the county. In addition to the exposed ledges of Trenton along the Mississippi bluffs, ledges of this formation are seen in a ravine in section 27, Peru township; there are some good exposures fifteen or twenty feet in thickness, at Thompson's mill, near Sageville, in the same township; and there are a few outcrops for a short distance along the stream, above the mill. Beds intermediate in character between Galena and Trenton occur at the foot of the bluff, by the side of the road leading from Sageville to Dubuque.

Lithological and faunal characteristics.—Counting all as Trenton above the Saint Peter and below the level of the dolomitized beds,—the Galena of authors,—the formation may

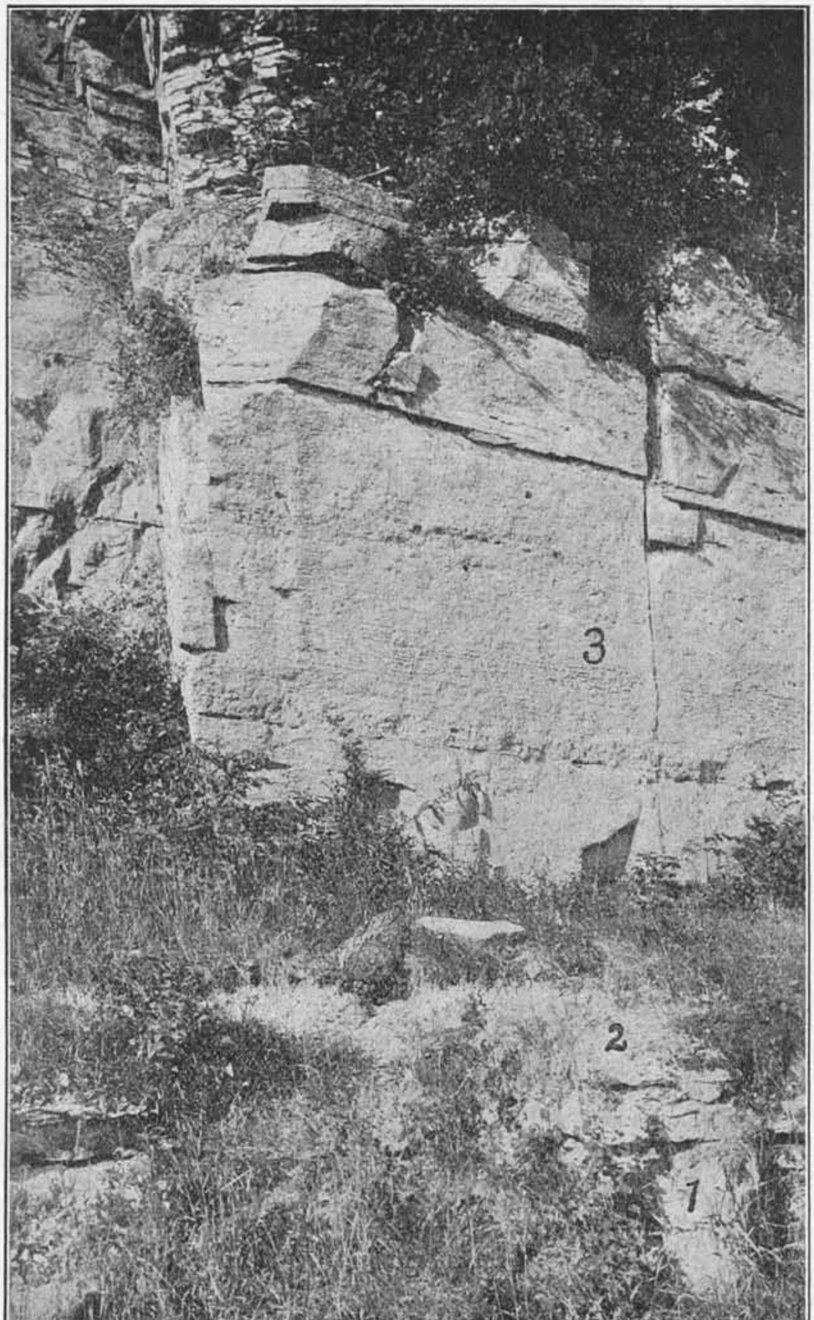

PLATE 5. View three-fourths of a mile below Specht Ferry, showing, in ascending order: 1. Saint Peter sandstone. 2. Basal shale. 3. Lower Buff beds. 4. Thin, brittle, blue beds.

be divided into a few recognizable divisions possessing distinctive lithological characteristics. The first member, resting on the Saint Peter sandstone, is a bed of bluish or greenish shale which weathers on exposure to ashen or yellow colors. In the report on Allamakee county, Volume IV of the present series of reports, this member is called the *basal shale*. It is very constant at this horizon so far as observations have been carried in Iowa; and reports indicate its presence very generally at the same geological level, in Wisconsin and Minnesota. The basal shale in Dubuque county will average about three feet in thickness, while farther north its thickness is increased to five or six feet. So far as noted it is quite barren of fossils; commercially it is of little importance.

Overlying the basal shale there are from eighteen to twenty feet of heavy-bedded, magnesian limestone, which, in the geology of Iowa and Wisconsin, have generally been known as "The Lower Buff Beds." The lower buff beds are best seen at the base of the bluffs, three-fourths of a mile below Specht Ferry. The individual layers vary from eight or ten inches to more than three feet. They are intersected by joints which cut almost vertically, and it is a smooth joint face, embracing the entire thickness of the beds, that is seen at the point referred to. The beds are earthy, impure, non-crystalline, and otherwise imperfect dolomite, very different from the coarse, granular, rough-surfaced, crystalline dolomite making up the typical portions of the overlying Galena. They are nevertheless hard and firm, and well suited for heavy masonry. The beds of this horizon are extensively quarried in the neighborhood of Minneapolis and Saint Paul, and, by reason of proximity to market, possess there no small degree of commercial value. In Dubuque county they have been quarried on a small scale in section 10 of Peru township; but in general they are neglected in Iowa, other formations furnishing desirable quarry products at localities less remote and less inaccessible from the points where building stone is in demand. Owing to the small number of natural exposures, and the still smaller number of quarries which would afford opportunities for anything like thorough investigation, no satisfactory report can be made on the fauna of the lower buff beds. Organic remains are certainly very scarce, if they are not entirely absent in identifiable form. At least none which could be specifically or even generically recognized were seen at the few points where the beds are in position to be examined.

Next in order of superposition is an assemblage of thin layers of bluish, fine-grained, brittle, fossiliferous limestone, equivalent to part of the "Lower Blue Beds" of some authors. These thin beds reach a thickness of twenty feet. They afford an example of the typical blue Trenton, the "Blue Fossiliferous Limestone" of Owen's earlier report, the "Saint Peter's Shell Limestone," in part, of a report of later date. These beds weather to a drab, or sometimes to a light buff color. The layers are thin, and the bedding planes are very uneven and undulating, producing considerable variation in the thickness of the individual beds. In weathered exposures the shaly partings between the layers vary from a fraction of an inch to more than an inch in thickness, so that in such thin-bedded material there is the appearance of a large proportional amount of shale. The shale in these partings is, in places, quite bituminous; when lighted it burns freely with bright flame, emitting the odor and the dense smoke which usually attend the burning of bituminous matter. In unweathered parts of the formation the shale in the bedding planes is hard and compact, so much so that in a fresh vertical section the several beds seem to blend homogeneously one into the other through thicknesses of four or five feet. At the quarry, in section 10, Peru township, this feature is quite marked. The quarry is worked at the end of a high, sharp ridge with steep sides, so that there are weathered surfaces at both ends of the quarry face. In the middle of the face the layers of the lower blue beds are apparently blended together, the partings showing but little difference in hardness and compactness from the purer calcareous portions of the deposits; while to the right and left, in the zones of weathering, as the natural surfaces of the two sides of the narrow ridge are approached, the thin bedding becomes oovious by the picking or weathering out of the less calcareous bands. These beds are well exposed, at short intervals, from Waupeton to Eagle Point, Dubuque. They make up the greater part of the section seen at the old Thompson mill at Sagetown. Everywhere they are fossiliferous, but the fossils are intimately blended with the matrix and are seen to best advantage when the layers are split horizontally. The most common species are *Rafinesquina alternata* Conrad, *Strophomena planumbona* Hall, a species which is sometimes of late identified with *S. rugosa* Raf., *Plectambonites sericea* Sowerby, *Orthis plicatella* Hall, *Orthis subæquata* Conrad, *Trochonema umbilicata* Hall, and fragments of a number of different species of trilobites.

Above the thin, brittle layers just described are five feet of heavier, coarser layers, not very fossiliferous, some of the ledges reaching a thickness of fifteen inches. These beds resist the weather admirably. They are followed by five feet of thinner, bluish beds, weathering brown, of coarser grain than those below, and not so fossiliferous. Adding these two members the total thickness of the division to which the term "Lower Blue Beds" has been applied in Wisconsin, is, in Dubuque county, thirty feet.

Above the lower blue beds are twelve feet of bluish or greenish shale, very soft and plastic, as a rule, but containing irregularly distributed through it, thin beds and thin lenticular sheets of limestone. The bed now under consideration corresponds to the "green shales" of Minnesota. The limestone flakes and thin sheets interbedded with the clay are very fossiliferous, consisting in most instances of crushed and broken brachiopod shells cemented together. The characteristic species of this horizon are *Orthis tricenaria* Con., and *Orthis subæquata* Con. but *Strophomena planumbona* Hall is a not uncommon fossil, and dismembered portions of *Ceraurus pleurexanthemus* Green are found occasionally. Toward the Minnesota line this shale bed attains a much greater thickness than it has at any point in Dubuque county, reaching as much as thirty or forty feet in the neighborhood of Decorah and Waukon. The limestone beds associated with the shale are also more numerous and more persistent farther north, and are richer in organic remains. This is one of the most constant and most easily recognized members of the Trenton limestone in the Mississippi valley, but it evidently thins out, as do most of the other shale beds, as it approaches the region where the Galena limestone phase of the formation is best developed.

Lying upon the "green shales" is a bed of bluish, rather coarse-grained limestone, twenty-five feet in thickness, with disseminated, unrecognizable fossils, and made up of thin layers having a thickness ranging from three to six inches. Next in order are five feet of shales, or shaly limestones, or shales interbedded with thin seams of limestone. This bed varies greatly in the relative proportions of the argillaceous and calcareous matter which it contains. *Orthis testudinaria* Dalman, which is not seen below the top of the "green shales," is very common at this horizon, and here also is found *Orthis bellarugosa* Conrad. Associated with the species named are *Orthis plicatella*, *Rafinesquina alternata*, and *Plectambonites sericea*. The Trenton phase of the limestone never extends, in Dubuque county, above this last shale horizon, while at Eagle Point, Dubuque, the Trenton ends and the Galena begins at the top of the *Orthis subæquata* shales.

The foregoing general description of the Trenton limestone is based upon the following typical sections:

Three-fourths of a mile below Specht Ferry, along the railway track, there are some good exposures which show:

		FEET.
6.	Steep slopes and vertical cliffs to summit of bluffs; the slopes covered with loose fragments, talus or scree; cemented in places, particularly on the lower slopes, with calcium carbonate deposited from springs; not measured..........	

5.	Thin-bedded, brittle limestone in flexuous layers; the limestone fine-grained and fossiliferous; the layers separated by shaly partings; a vertical exposure of..	8
4.	Heavy-bedded, magnesian, non-crystalline limestone, the "Lower Buff Beds" of authors..................	20
3.	Basal shale, weathering to yellowish and ashen tints..	3
2.	Saint Peter sandstone, much stained with iron oxide, in rather definite layers............................	5
1.	Unexposed to level of river............................	25

A better section, giving more complete details of the Trenton limestone in this part of Iowa, is seen in the first ravine below Specht Ferry, only a few rods southeast of the station. This section shows:

		FEET.
11.	Thin-bedded, brown dolomite with shaly partings. (Galena)..	4
10.	Thin-bedded, imperfectly dolomitized limestone, with fossil brachiopod shells only slightly changed; the limestone brown, earthy, non-crystalline, but evidently of the Galena type......................	3
9.	Thick, earthy, imperfectly dolomitized beds. (Galena.)	3
.8	Thin limestone beds with much shale in the partings; in part a true shale. This member is almost entirely shaly a few rods above the station on the road leading to Dubuque. Fossils are numerous, the most common species being *Orthis testudinaria*, *O. bellarugosa*, *O. plicatella*, *Rafinesquina alternata*, and *Plectambonites sericea*............................	5
7.	Limestone, bluish, rather coarse grained, with disseminated fossils; in beds varying from three to six inches in thickness............................	25
6.	Bluish or greenish shale containing occasional thin beds or discontinuous flakes of limestone; the characteristic fossils are *Orthis subæquata* and *O. tricenaria;* the "Green Shales" of the Minnesota geologists..	12
5.	Thin-bedded, bluish, rather coarse grained limestone, weathering brownish in color....................	5
4.	Limestone in rather heavy layers which range up to fifteen inches in thickness; bluish on fresh fracture but weathering to buff on exposure..............	5
3.	Brittle, fine grained, blue limestone, very fossiliferous, breaking up on weathered surfaces into flexuous layers about two inches in thickness.....	20
2.	Lower buff beds, exposed, about....	8
1.	Unexposed to level of water in river, about	45

Numbers 2 to 8 in the above section belong to the non-dolomitized portion of the formation, which has usually been recognized as the Trenton. Numbers 9 to 11 represent the dolomitized phase which has quite generally been referred to a distinct formation and called the Galena limestone. A few rods southwest of the Specht Ferry station, on the Dubuque road, a small gorge cut in the bluff on the east side of the road reveals essentially the same section as that just recorded. From the top of the Saint Peter sandstone to a plane above the middle of number 3, a distance vertically of about fifty feet, the beds are not exposed, but from number 3 up, the succession is just the same, except that number 8 is practically a pure shale which weathers into a plastic, unctuous, blue or yellow clay.

A quarry in section 10 of Peru township, two miles below Specht Ferry, gives an artificial section which shows some details not seen in the natural exposures. At this point we have:

	FEET.
5. Blue, thin-bedded limestone, at the top of the section.	2
4. Shale, the equivalent of the "Green shales"	8
3. Heavy ledges of fairly good building stone, bluish, but weathering into buff on exposed surfaces, equivalent to numbers 4 and 5 of the Specht Ferry section....	10
2. Thin-bedded, brittle, blue, fossiliferous limestone...	16
1. Heavy lower buff beds, good quarry stone............	10

The quarry here described, as noted on a preceding page, is worked across the end of a narrow, sharp ridge. In the middle of the quarry face, where it has not been exposed to weathering, number 2 appears to be made up of heavy beds four or five feet in thickness. The ordinary bedding planes which, on weathered surfaces, divide this member into thin, flexuous layers only a few inches thick, are brought out conspicuously only by exposure to the weather. Before such exposure the alternating bands of calcareous and more argillaceous material appear equally solid and are blended together so as to present the superficial appearance of homogeneous, massive ledges. Toward the sides of the quarry face, near the exposed surfaces of the ridge, number 2 assumes its usual characteristics of thin-bedded limestone with shaly partings. In the loose material at the foot of the vertical cliff which now forms the breast of the quarry there were slabs of fossiliferous limestone containing *Orthis subæquata* and the associated fauna of the green shales horizon.

The exposures above the mill near Sagetown belong to numbers 2 and 3 of the Specht Ferry section. At the lime works near Eagle Point, Dubuque, there are beds carrying the green shales fauna, the equivalent of number 6, exposed immediately beneath the Galena limestone.

GALENA LIMESTONE.

The phase of the Galena-Trenton, which has come to be known as the Galena limestone, attains a greater development and has a much wider distribution in Dubuque county than the Trenton. In its typical exposures the Galena is a rather dark, buff-colored, granular, highly crystalline dolomite; but the formation varies considerably at different levels throughout its thickness, and it varies also, to some extent, in different localities. At no one point was it possible to get an entire section of the Galena limestone, but all parts of the formation—from its base in contact with the Trenton to its uppermost thin, earthy, almost shaly layers in contact with the overlying Maquoketa—may be studied satisfactorily within the city of Dubuque. The following specific descriptions and detailed sections, better than any general discussion, will convey some idea of the characteristics of this formation as it is developed in the area under consideration. One of the best sections is that at the Eagle Point Lime Works. Beginning at the top of the bluff it shows:

	FEET.
15. Loess-covered slope above the outcropping ledges of Galena limestone, culminating in a prehistoric mound at the summit of the bluff..................	15
14. Ledges of well dolomitized Galena, varying from two to three feet in thickness.........................	10

13. Two or three rather heavy ledges containing large numbers of the problematic fossil, *Receptaculites oweni* Hall. Receptaculites is found sparingly in other members of the section. At this horizon, which will be called the Receptaculites zone, it is exceedingly abundant.............................. 10
12. Heavy-bedded, typical Galena, hard, crystalline and relatively free from chert; in ledges three to six feet in thickness.................................... 70
11. Bed containing pockets of calcite; the calcite in some cases forming large crystals...................... 3
10. Bed containing large quantities of chert. 4
9. Ledges showing the characteristics of the typical Galena, hard, compact, crystalline, completely dolomitized, with small amount of chert................ 18
8. Thick, massive beds with large amount of chert..... 12
7. Thick beds of crystalline dolomite, the ordinary type 6
6. Ledge varying in texture, containing small pockets of calcite and some chert; a single specimen of Receptaculites found in this ledge.......................... 4
5. Heavy ledge nearly on a level with the top of lime kiln.. 3
4. Dolomite varying in aspect according to degree of weathering; at Eagle Point showing bedding planes 10 to 18 inches apart 15
3. Massive, crystalline dolomite; bedding planes almost completely obliterated.............................. 20
2. Incompletely dolomitized beds with shaly partings at intervals of six, eight, or ten inches 10
1. Basal ledge of Galena, beginning on top of Trenton limestone and shale bearing *Orthis subæquata* and associated fauna; this lower bed is earthy, incompletely dolomitized, and weathers below into a dark brown or reddish ferruginous clay.................. 2

A few feet of shales and non-dolomitized limestone, carrying the green shales fauna, are exposed at the foot of the vertical cliff a few rods south of the lime kiln. The base of the Galena at this point is about thirty feet above the medium summer stage of water in the Mississippi river at the Eagle Point ferry landing. The exposure of the Trenton shale and limestone referred to coincides in position with one of the numerous small anticlinal folds seen in this county. The quarry worked to supply material for the lime kiln is located north of the axis; and in the quarry the dip, which is a little east of north, amounts to about one foot in twenty. All the beds of the Galena are intersected with joints which trend and hade at different angles. The joint faces are usually, in some instances heavily, coated with stalagmite.

The chert-bearing beds, which begin in number 6 and range up into the lower part of number 12, constitute a well marked horizon, the significance and importance of which will be brought out in the discussion of the economic products of the Galena limestone. This chert horizon is well illustrated at the foot of the bluffs all the way from Seventeenth street southward to the mouth of Catfish creek. It is exposed through a thickness of fifteen or twenty feet, on the south side of Julien avenue, a short distance above Bluff street. At the Fenelon Place elevator on Fourth street the nodules and concretions of chert characteristic of this zone are quite conspicuous, and range up through a thickness of thirty feet. The same zone is well exposed in the cliffs along the track of the Illinois Central railway, from a mile to a mile and a half south of the station. From the Eagle Point anticline the beds dip somewhat uniformly toward the south or southwest, and so below the mouth of Catfish creek the chert beds soon disappear below the level of the railway embankment.

In the cliffs along the south side of Julien avenue the chert beds are followed by heavy ledges corresponding to those forming the upper sixty feet of number 12 of the Eagle Point section. These ledges are overlain by Receptaculites beds ten feet in thickness, as is well shown by the recently quarried massive layers a few yards south of the point where Hill street joins the avenue. Above the Receptaculites beds, which are the equivalent of number 13 at Eagle Point, there may be made out, on the east side of Hill street, thirty feet of only moderately heavy, thoroughly dolomitized beds, the basal part of which, only, is represented by number 14 of the detailed section above described. Numbers 12, 13 and 14 constitute the characteristic part of the Galena. The beds in general are thick, heavy, hard, completely dolomitized, rather crystalline and relatively free from chert. It is these beds which form the conspicuous walls and precipices on both sides of Fifth street, beginning a short distance above Bluff and continuing well up toward the summit of the hill. To them, it is, we owe the picturesque buttressed walls so impressively prominent about the middle height of the bluffs at so

Fig. 46. Towers of Galena limestone above level of chert beds; seen in valley of Catfish creek west of Rockdale.

many points within the city of Dubuque. They form the majestic towers and castles (Fig. 46) seen from the trains of the Illinois Central railway a short distance west of Rockdale; while the vertical walls which guard the narrow valley of Catfish creek in the vicinity of Dubuque's grave, are examples of Nature's masonry built of these same ledges. Beds of this horizon showing the same characteristics are seen in the picturesque castles and mural escarpments in the valley of the Little Maquoketa, from one to two or three miles southwest of Durango. It will be unnecessary to mention all of the numerous localities at which this characteristic phase of the Galena is exposed. The point most distant from Dubuque where it was observed, with features practically unchanged, was in the valley of the small creek which traverses the W. $\frac{1}{2}$ of the Ne. $\frac{1}{4}$ of Sec. 22, Jefferson Tp.

Here the stream flows at the foot of vertical walls of typical Galena limestone, thirty to forty feet in height.

As noted above, thirty feet is assigned to the somewhát arbitrary division of the Galena limestone, which lies next above the Receptaculites zone. About the middle of this

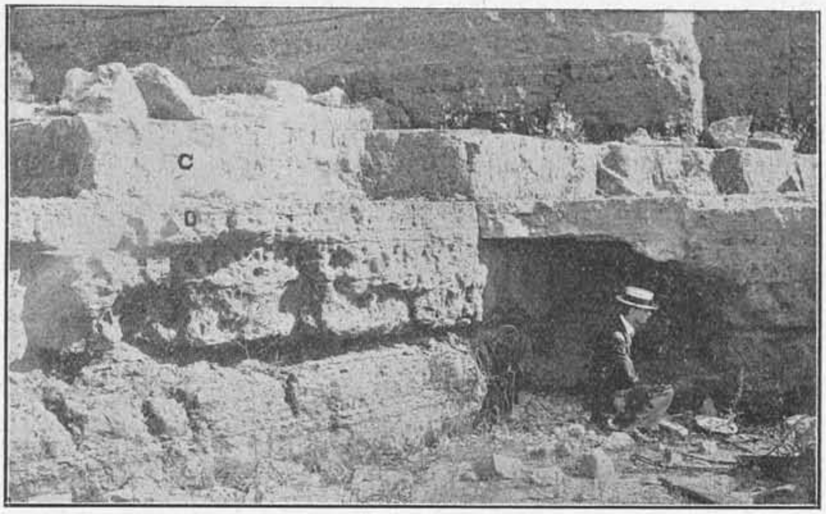

Fig. 47. Galena limestone at level of "cap rock." C, Cap rock; D, Thinner layer below cap rock.

division occurs the "cap rock" of the miners, a heavy firm layer about two and a half feet in thickness. Below the heavy "cap rock" there is usually another firm layer eight to nine inches thick, below which there are softer beds which disintegrate readily and produce caverns of varying dimensions, particularly where the strata have been cut by joints. These features are well shown in Figure 47. Toward the top of this member the beds are somewhat thinner than near the base, and throughout its whole thickness the bedding planes are nearer together than in numbers 12 and 13 of the Eagle Point section. Few of the layers exceed two and a half feet in thickness, and many are much less. In this horizon are located most of the quarries, which in this vicinity, furnish the material for heavy, substantial masonry.

Above the division just described the Galena becomes thin-bedded, earthy, soft and non-crystalline. Dolomitization is imperfect. The layers range from three to ten or twelve inches in thickness; the thicker beds being near the base, and the layers becoming progressively thinner toward the top. Shaly partings between the strata are more common in this division than elsewhere in the formation under discussion; the thickness of the bands of shale, in the upper part, become equal indeed to the thickness of the alternating layers of limestone. As a matter of fact the limestone, in the very upper part, is not infrequently reduced to mere rows of disconnected nodules embedded in clay. This is the uppermost member of the Galena limestone. It is overlain directly by the Maquoketa shales. The total thickness is somewhat variable, but it will average about thirty feet. The division is not definitely separated by any well marked line from the member below. It has beds of fairly good quarry stone toward the base; the calcareous bands and nodules of the upper part are practically worthless. The member here discussed is exposed in an abandoned quarry located in the angle north of Fifth and east of Hill street. The very uppermost part of it is seen, in contact with the base of the Maquoketa shales, at the brow of the hill on West Eighth street, a few yards east of Pine. It has been quarried quite extensively on the north side of West Fourteenth street, near Cox, and at a number of other places a block or two north of Fourteenth street in West Dubuque. At the quarry near Cox street three or four feet of Maquoketa shales occur above the Galena at the top of the excavation. A number of quarries are worked in the lower part of the thin-bedded Galena, and down into the upper part of the underlying member, along Dodge and South Dodge streets.

At many other points within the city limits are the upper beds of the Galena exposed, but the quarries and natural sections already noted are sufficient to illustrate the characteristics of this formation. So far as observed these characteristics are very constant and are easily recognized. The total thickness of the Galena limestone at Dubuque includes numbers 1 to 13 of the Eagle Point section, which, to the top of the Receptaculites zone, gives an aggregate of 177 feet. To this must be added the Hill street section, from the top of the Receptaculites zone to the top of the abandoned quarry between Hill and Fifth streets, or up to the contact with the Maquoketa shales on West Eighth street. This gives for the part above the Receptaculites beds:

	FEET.
15. Thin-bedded Galena limestone, earthy, non-crystalline; the layers ranging from ten or twelve inches near the base to less than three inches in thickness near the top; upper part of this member very shaly; carries as fossils *Lingula iowensis*, *Liospira lenticularis* and *Conularia trentonensis*....................	30
14. Well dolomitized Galena in layers ranging from one to two and a half feet in thickness; with softer beds near the middle, which frequently disintegrate so as to form caverns; basal part only, of this member, represented above the Receptaculites beds at Eagle Point..	30

Adding the sixty feet of numbers 14 and 15 to the 177 feet represented by numbers 1 to 13 at Eagle Point, the total thickness of the Galena limestone at Dubuque is found to be 237 feet.

Outside the city limits there are numerous exposures of the upper portion of the Galena, those corresponding to number 15 of the Dubuque city section being readily recognized by the earthy character of the rock, by the thin bedding, and by the relatively large amount of shale in the partings between the strata. The Graf quarry, a short distance west of Twin Springs, in the Sw. ¼ of the Se. qr. of Sec. 16, Center Tp., is worked partly in the upper member of the Galena, number 15, and partly in the better dolomitized beds, number 14, which lie immediately below it. Along the railway track, between Twin Springs and Graf, there are a number of rock cuts showing the upper, earthy beds; and in one of these cuts, the first southwest of the Graf quarry, the Galena is overlain by from four to six feet of Maquoketa shales. (Fig. 48.) As usual the

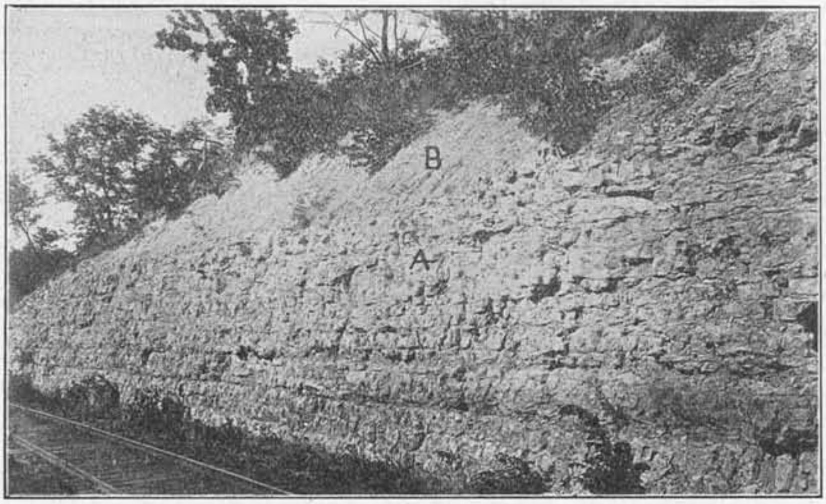

Fig. 48. A, Upper thin-bedded portion of Galena limestone; B, overlying Maquoketa shales.

Galena is nodular and shaly toward the top, but the transition to the Maquoketa is, nevertheless, very abrupt. The same abrupt change in the character of the sediments is strikingly shown on West Eighth street in the city of Dubuque, and at all the numerous points throughout the county where the contact of the two formations was observed. The Se. ¼ of Sec. 20, Center Tp., affords many good exposures of the upper portion of the Galena and of its contact with the overlying Maquoketa. There is here a strong dip to the southwestward, so much so that a short distance beyond Graf, less than a mile from the locality above noted, the Galena has disappeared below the bed of the small stream, and the level of the railway grade is forty or fifty feet above the base of the Maquoketa. In section 31 in the northern part of Jefferson, in T. 91 N., occur the last exposures of the Galena limestone in this direction, in the county. Barometric measurements give the formation here a thickness of about 200 feet. The beds as a whole are less massive, and less compact and crystalline, than those making up the middle portion of the Galena at Dubuque. The typical characteristics of the formation seem gradually to fade out toward the northwest, so that in northern Clayton, southern Allamakee, and central Winneshiek, dolomitization has affected only a small part of the layers which constitute the typical Galena in the lead mining districts of Iowa, Wisconsin and Illinois.

MAQUOKETA SHALES.

In Dubuque county the formation which immediately overlies the Galena limestone, as this limestone is described in the foregoing section, is argillaceous throughout its entire thickness. There are a few bands containing more or less of calcium carbonate, but none of the beds could properly be characterized as true limestone or dolomite. The formation is found, however, to be exceedingly variable, lithologically and paleontologically, when traced through the counties north and northwest of Dubuque. The variations referred to are local, very great diversity occurring not unusually at localities separated by only a few miles. In a general way, though it is not universally true, the formation becomes more calcareous toward the northwest; and, as at Peterson's spring, in Fayette county, it acquires locally bands of true limestone embedded in bluish or greenish clay.

Since the presence of a body of shale between the Galena and Niagara limestones was announced by Hall in 1858, the formation has received a large share of attention at the hands of geologists. Scarcely any formation in this geological province has been written about more persistently; scarcely any has been more misunderstood; with respect to no other has there been greater diversity of judgment and interpretation; in no case is it more obvious that some of the latest attempts to harmonize discrepant opinions have involved the whole subject in more inextricable confusion. The terms Hudson River shales, Cincinnati shales, Utica shales, Maquoketa shales, together with numerous less generally known local names, have all been severally applied to the formation in question, as it is developed in Iowa, Minnesota, Wisconsin, and Illinois. For the literature of the subject the reader is referred to the writings of Hall,* Meek and Worthen,† White,‡ Chamberlain,§ Strong,‖ James,** Winchell,†† McGee,‡‡ and Sardeson.§§

Without attempting to harmonize all the discrepant opinions held and expressed respecting the name of the formation, or the stratigraphic limits which should be assigned to it, it is sufficient to say that, so far as Dubuque county is concerned, no confusion need arise from the use of the term Maquoketa shales, as applied by White; nor will anything be lost either in the way of clearness or scientific accuracy if, stratigraphically, the formation is limited by the top of the great body of dolomite belonging to the Trenton series, and the base of another great body of dolomite which belongs to the Niagara series. These two limits are here perfectly definite and precise; their use is in accord with the most rigid of scientific requirements; and the great body of shale—200 feet in thickness—which lies between them, is sharply set off by lithological and paleontological characters from both dolomitic formations. Among the authors who have recently written on the subject, one proposes to draw the line between

*Report on the Geol. Surv. of Iowa, by James Hall, 1858; and Reports on the Geol. Surv. of Wisconsin, 1861 and 1862.

†Proceedings Phil. Acad. of Sci, 1865; and also Geol. Surv. of Illinois, Vols. I, II, III, and VII.

‡Report on the Geol. Surv. of Iowa, by Charles A. White, 1870.

§Geology of Wisconsin, survey 1873-1877, 1877.

‖Geology of Wisconsin, survey 1873-1877, 1877.

**American Geologist, Vol. V, 1890; Pro. Am. Ass'n for the Adv. of Sci., Vol. XXXVIII, July, 1890.

††See Reports on the Geol. Surv. of Minnesota; particularly Vol. III, Part II, of the Final Report, introduction, page CI.

‡‡Pleistocene Hist. of Northeastern Iowa; U. S. Geol. Surv., Vol. XI, 1891.

§§*American Geologist*, Vol. XVIII, p. 356; and same Journal, Vol. XIX, 1896, 1897.

the Galena and the Maquoketa about the top of the Receptaculites zone, and so transfer some fifty or sixty feet of dolomite to the Maquoketa formation; but such a proposition can scarcely be taken seriously.

From the Galena the Maquoketa formation differs as much in respect to the physiographic conditions under which it was deposited, as in the matter of lithological and paleontological characters. During at least the later part of the age represented by the Galena limestone, the area now occupied by Dubuque county was a part of an isolated, or partially isolated, sea basin in which the waters were bitter, and concentrated to such an extent as to produce dolomitization of all calcareous sediments. With the beginning of the age now called Maquoketa, this land-locked sea with arid shores gave place to a body of water communicating freely with the open ocean; and mechancial sediments, indicative of generous rainfall, were laid down in sea water of normal density. Taking prompt advantage of the new physiographic conditions, types of life,—some new to the region, and some of species which had been present when the normal waters of the Trenton sea occupied the area,—established colonies which soon spread a dense population over the new sea bottom. Not all the old forms came back, and some that did, did not return until the Maquoketa age was fully half complete. *Plectambonites sericea*, for example, is common in the strata immediately above the "Lower Buff Beds" of the Galena-Trenton. It disappeared from this particular part of the province before the close of the Galena; it is absent from the lower half of the Maquoketa; but it reappears in force above the middle of the formation, and is in places one of the most abundant and characteristic fossils in beds which lie within a few feet of the base of the Niagara.

While the upper part of the Galena contains a large proportional amount of argillaceous material, calcareous beds predominate; and the effects of the conditions which brought about dolomitization are strongly expressed up to the dividing line which marks the abrupt beginning of the Maquoketa. A number of points at which the change from Galena to Maquoketa may be seen, have been already mentioned; and at all these points the transition is indicative of a very sharp break. Even after the Maquoketa began, the conditions were for

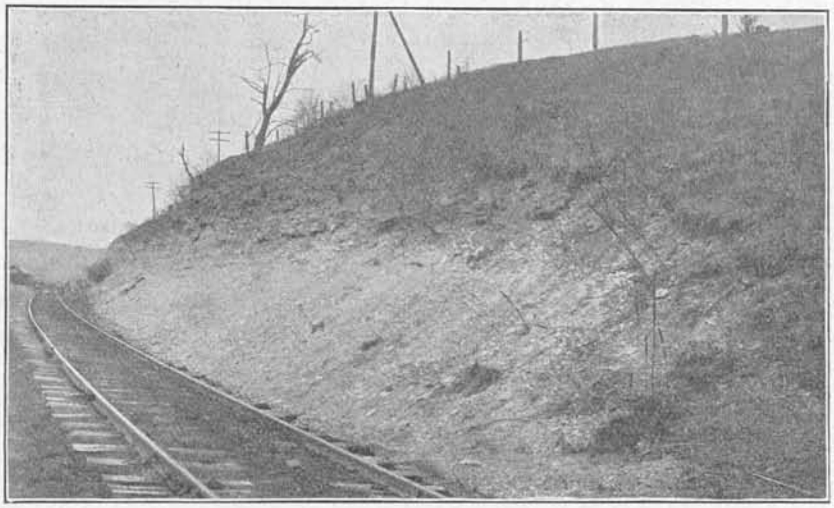

Fig. 49. Railway cut in Maquoketa shales west of Graf.

some time unstable, and fluctuations are recorded in the varying character of the deposits. All the characteristics of the lower part of the shale may be studied within the limits of the city of Dubuque. The exposures on the slope of the bluff on West Eighth street, and those at the top of the quarries in many parts of the city, as on Fourteenth street, show the variable character of the first five or six feet of the shale, and the sharp manner in which it is set off from the underlying Galena. The mineral shafts on the high ground, back from the face of the bluffs, not infrequently penetrate fifty or sixty feet of shale before reaching the Galena. It is the region, however, in the neighborhood of Lattners and Graf, in Center township, which has become classic in connection with the study of the formation now under consideration. Here on the banks of the Little Maquoketa are the typical exposures to which Hall and White, and James, and many others less prominent, have resorted for the information made use of in contributing to the literature of the subject. From the little stream that flows at the foot of the bluffs in which the exposures occur, the formation gets the name applied to it by White. To this locality the student must to-day resort, if he would study, with greatest success and least labor, the characteristic aspects of the deposits. About one-half mile west of Graf station, the Great Western railway has made a cut through the Maquoketa shales (Fig. 49) at the level of the principal section studied by Hall and White. It was this cut, together with a number of exposures in adjacent washes and ravines, which was examined by James. In this cut the writers of the present report noted the following section:

	FEET.	INCHES.
17. Drab to black, argillaceous, unfossiliferous shale	2	
16. Sixth Orthoceras bed; brownish, hard, granular, non-fissile shale, with numerous specimens of the minute, brad-like shells of *Coleolus iowensis*, some small gastropods, a few specimens of *Orthoceras sociale*, together with cephalic shields and pygidia of *Calymene mamillatus*	1	2
15. Shale, drab, very fissile, somewhat sandy, no fossils	1	4
14. Fifth Orthoceras bed; light brown, earthy, non-laminated, rather hard layer which some writers have described as limestone; not very calcareous; crowded with shells of *Orthoceras sociale*, which are generally crushed and otherwise imperfect; some of the partially decomposed shells still retaining the original nacreous luster	1	
13. Fissile, slaty shale, dark gray in color, containing many blade-like, or sheath-like impressions of a fossil which Ulrich has described under the name of *Spatiopora iowensis*	0	6
12. Fourth Orthoceras bed, lithologically the same as number 14, Orthoceras very numerous and crowded, more perfect than in 14.	0	6-8
11. Shale varying in thickness, dark gray in color.	0	1-3
10. Third Orthoceras bed, resembling 12 and 14..	0	10

9. Thin bed of dark, fissile shale; irregular as to thickness, in some places reduced to a mere parting	0	1-3
8. Second Orthoceras bed, lithologically like 10, 12 and 14	1	
7. Shale, dark brown, imperfectly laminated, rather coarse-grained and earthy, crowded with *Diplograptus peosta*	0	5
6. First Orthoceras bed, like number 8	0	4-8
5. Shale, brown, fissile, fossiliferous	0	7
4. Shale, earthy, granular, non-laminated; with many comminuted fossils and perfect shells of *Coleolus iowensis*, *Murchisonia gracilis*, *Liospira micula*, and other species	2	
3. Shale, dark brown, non-fissile, with a species of Lingula three-eighths of an inch long and one-fourth of an inch wide	2	
2. Shale, dark, bluish-black, fissile or slaty, containing large numbers of *Leptobolus occidentalis*, and two species of Lingula	2	2
1. Shale, brown or black, non-fissile, fossils rare, occasional specimens of a Lingula half an inch long and three-eighths of an inch wide	6	

Among the features of special interest in this part of the Maquoketa section are the Orthoceras beds, numbers 6, 8, 10, 12, and 14; the Spatiopora bed, number 13, and the Diplograptus bed, number 7. The layers in which Orthoceras occur are composed of hard, non-laminated rock resembling some phases of limestone or dolomite. They have indeed been described as limestones or dolomites by some of the writers who have discussed this section, but they are simply indurated beds of clay with which is mixed a small amount of calcareous material. The Orthocerata are crowded together and telescoped one into the other in a way that resembles the promiscuous arrangement of shells of other species of mollusks, which to-day, by the action of waves and tides, are heaped in winrows along the sea beach. The nature of the Orthoceras beds and the accompanying deposits, together with the width of the area over which they are distributed, precludes the hypothesis of a littoral or beach deposit; but indicates rather that these shells were tossed about and were finally spread, more or less evenly, over a considerable area of shallow-sea bottom. Number 13 is an exceedingly definite and well marked bed, consisting of dark, laminated shale divided into prismatic blocks by clean cut, intersecting joints. The feature, however, which is shared by no other member of the section, is the tapering, blade-like fossils that Ulrich has identified as Bryozoa and described under the name of *Spatiopora iowensis.* Ulrich* believes that these Bryozoa grew as encrusting films on the outer surface of the shells of *Orthoceras sociale;* and that by some process of maceration and compression the Orthoceras shell has completely disappeared, while the zoaria of the several encrusting colonies of Bryozoa have been preserved. The skeletal part of the organism which made these impressions was elongate-conical and sac-like as to structure, and the sac possessed thin, delicate, reticular walls. The thin-walled sac is now compressed, with the inner surface of one side in close apposition with the inner surface of the other. It is the inside of the sac that is generally presented to the observer, for in separating the shaly laminæ between which the fossils are embedded, one-half of what is left of the original structure usually adheres to each lamina. Occasionally the separation takes place in such wise as to leave parts of both halves of the compressed sac on one of the separated laminæ, and then it is seen that the outer and inner surfaces are markedly different in certain details of structure and color. Graptolite markings and impressions are common in nearly all the shaly portions of this part of the deposit; but bed number 7 is distinguished from all the rest by the great number of delicate stipes which it contains, and the remarkable perfection of their preservation. All, or practically all, of those occurring in this particular zone belong to the species *Diplograptus peosta* Hall. Indistinct impressions of a species

*The Geology of Minnesota, Vol. III, Part I, of the Final Report; p. 321.

which is probably *Diplograptus pristis* Hisinger, occur, sometimes in great numbers, at different levels, in the shaly portions of the section.

Owing to the rapidity with which the Maquoketa shales disintegrate as a result of weathering, exposures of the for-

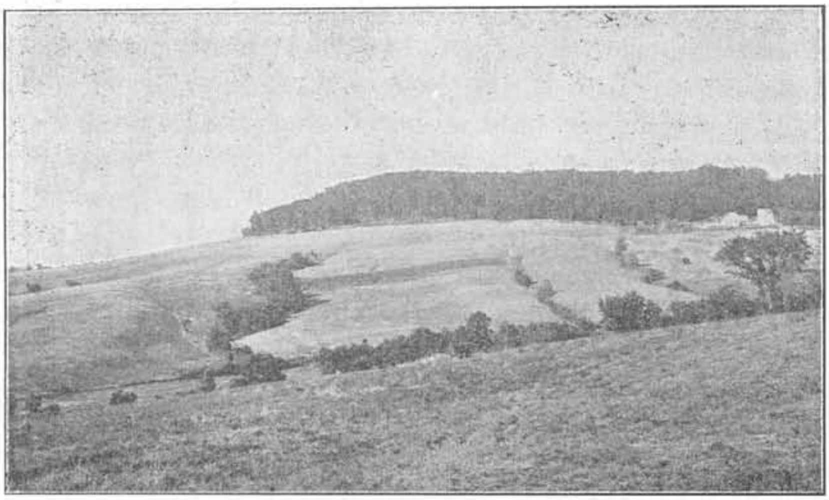

Fig. 50. View near Graf showing the effect of the Maquoketa shales on the topography. The rounded swells and long, cultivated slopes are underlain by shales; the steep, wooded hill in the distance is composed of the overlying Niagara limestone.

mation soon become concealed with products of decay, and "sodding over" follows in a comparatively short time. The formation, accordingly, does not form permanent cliffs; continuous vertical sections of any considerable thickness are not to be found except in the bottom of some creek which is still vigorously scouring its channel; and exposures of any kind are comparatively few. The formation expresses itself in the landscape in gracefully rounded swells and long, gentle slopes (Figure 50). The Little Maquoketa, in the central part of Center township, washes the base of steep bluffs of Galena limestone; away up on the rim of the valley, 200 feet higher, the Niagara limestone forms a nearly vertical escarpment; between the two cliff-forming limestones are the long, gently rolling and cultivated slopes of the Maquoketa shales, as is partly illustrated in the figure above referred to. On these long hillsides the rain, here and there, cuts gullies deep enough to expose the unweathered shale, and thus afford the student an opportunity to learn, though in a fragmentary way, the characteristics of the deposit at different altitudes above its base. A number of these gullies are found southeast of the stream in section 29, and on the opposite side of the stream in section 20 of Center township. One of the best sections of this formation, so far as observed, is that which is found in the bed of an intermittent creek in the Sw. ¼ of the Se. qr. of Sec. 20. The ravine cut by the creek is followed by the road leading westward from Hill's mill. Here the following, which may be called Hill's mill section, is exposed:

		FEET.	INCHES.
30.	Blue and green plastic clay shales concealed in slope, except at contact with number 29; thickness not measured		
29.	Shale, yellowish; weathering to plastic clay	1	
28.	Indurated, stony beds, yellow	0	3
27.	Shale, laminated, fissile, yellow	2	
26.	Dark drab, non-fissile shale containing a few specimens of a small Orthoceras, a different species from *O. sociale* Hall	0	3
25.	Fissile, slaty, bluish shale; weathering yellow	0	6
24.	Yellow, stony, calcareous, non-laminated bed, with some specimens of *Murchisonia gracilis* and numerous small lingulæ	3	
23.	Drab, slaty shale; equivalent to numbers 16 and 17, Graf section	2	
22.	Shale	1	
21.	Fifth Orthoceras bed; forty feet above base of the formation	1	
20.	Shale; equals number 13 at Graf	0	6
19.	Fourth Orthoceras bed; equals number 12	0	6
18.	Thin seam of shale; equal to number 11	0	2
17.	Third Orthoceras bed; equal to number 10	0	10
16.	Shale; equal to 9	0	2
15.	Second Orthoceras bed; equal to number 8	0	10
14.	Drab, fissile shale	0	3
13.	Non-laminated shale, with shells of *Murchisonia gracilis*	0	3
12.	First Orthoceras bed; equals number 6 of Graf section	0	6
11.	Brown, fissile shale; equals number 5 of Graf section	1	

10.	Non-laminated, fossiliferous bed; equal to number 4	2	
9.	Brown, fissile shale; equal to number 3	2	
8.	Earthy, fossiliferous shale, not represented at Graf	0	2
7.	Blue, slaty shale, with the fossils of number 2 at Graf	1	2
6.	Hard, yellowish, barren shale	0	3
5.	Laminated shale with the large lingulæ of number 1 at Graf	13	
4.	Bluish or drab, laminated shale, with traces of graptolites and numerous specimens of Leptobolus and Lingulá in the lower part; upper part barren	8	
3.	Bluish, unfossiliferous, laminated shale	8	
2.	Shale, variable in color and texture, but in general non-laminated and coarse, very fossiliferous, carries a small species of Orthoceras, *Liospira micula*, *Pleurotomaria depauperata*, *Hyolithes parviusculus*, *Cleidophorus neglectus*, and *Ctenodonta fecunda;* the last named species very common	2	
1.	Upper beds of the Galena limestone showing the usual thin layers, layers becoming progressively thicker from above downwards; exposed in vertical walls in bank of stream	15	

In the bottom of the creek in which the above section was observed, and in some of the side ravines, the contact of the Maquoketa and Galena is well shown. From observations in the bed of the stream, made at what seemed to be the line of contact between the two formations, James* believed there were indications of pre-Maquoketa erosion of the Galena, and reached the conclusion that the shales are separated from the limestones by an unconformity. It is just possible that the author referred to, with observations limited to the narrow dimensions of the creek bed, was misled by overwash of clay upon recently eroded Galena. At all events, in making the present survey, evidences of unconformity, indicated by an intermediate erosion interval, were carefully sought, without success, at all the points where the contact plane is exposed. Though the change from limestone to shale is quite abrupt, the sedimentation planes on the two sides of the contact line,

*American Geologist, Vol. V, p. 344, 1890.

in Dubuque county, are everywhere parallel; the continuity was evidently unbroken.

In this connection, however, it may be well to say that, notwithstanding the absence in this county of evidence of unconformity due to overlap upon an eroded surface, there are reasons for believing that in some localities the Maquoketa may rest unconformably on the Galena-Trenton. It has been said that probably the Galena limestone owes its dolomitic character to the fact that, toward the close of the interval represented by the formation named, the area now occupied by the lead-bearing limestone was an isolated, or partly isolated, basin in which the sea waters were concentrated by evaporation. The city of Dubuque is located in what was the central part of this land-locked basin. In order that the concentration necessary to produce dolomitization of the limestones might be possible, it is a fair assumption that the interval was one of arid climate, one in which loss by evaporation exceeded the volume of drainage waters received by the basin from the adjacent lands. For a large share of the Galena interval, on account of ineffective erosion, but little land waste found its way to the Dubuque region. The thin, irregular beds of limestone with shaly partings, in the upper part of the Galena, may be interpreted in two ways. The phenomena may mean that, before the Galena came to a close, rainfall increased, erosion became more energetic, and a greater proportionate amount of mechanical sediments was the logical result. All the facts, however, taken together, seem to point, not to any increased rate of erosion beyond what had taken place in the preceding portions of the arid Galena interval, but to constantly waning energy on the part of the life forms which contributed the limestone-making materials, owing perhaps to the fact that the increasing salinity of the waters rendered the conditions more and more unfavorable to the existence of life. It is upon beds laid down under the conditions described that the Maquoketa shales were deposited. As has been said, the change is abrupt.

The very first of the shales bear evidence of copious rainfall on land and normal conditions of salinity in the water. In the lower two or three feet of the shales there are many rolled pebbles of limestone, which must have been carried in from the sides of the basin; and while there is no evidence that the Galena limestone of our area suffered erosion before the deposition of shales began, the rolled pebbles and other materials at the base of the Maquoketa point to the possibility of erosion of contemporaneous beds not far away. Such an eroded surface, overlain by shale, may yet be found toward the northwest.

Number 2 of the Hill's mill section, the lowest member of the Maquoketa formation, may very properly be called the Ctenodonta bed. The characteristic fossils which it contains, on account of their great numbers and perfect preservation, are sure to arrest the attention of any observer studying the details of this part of the geological column, no matter in what part of the county exposures of this horizon may be found. Above the Ctenodonta zone, up to the first Orthoceras bed, the formation consists almost exclusively of blue or drab, indurated, slaty shales which break up into thin, hard flakes, but do not disintegrate into a plastic clay. There are occasional yellowish or brownish, non-laminated layers interbedded with the fissile shale, but the aggregate thickness of these is inconsiderable. The same conditions, practically, are continued through the Orthoceras beds and up to number 28 of the Hill's mill section. Above number 28 the formation changes suddenly, so that the line between 28 and 29 divides the formation into two very distinct portions which may be designated, respectively, the Lower and the Upper Maquoketa. The Lower Maquoketa, from fifty to sixty feet in thickness, is made up of the lean, non-plastic beds already described; the Upper Maquoketa is at first composed largely of green and blue, plastic, non-fossiliferous shales, but in the last twenty-five feet below the Niagara the shales give place to transition beds which are represented by thin layers of shaly, impure dolomite.

The Lower Maquoketa varies somewhat in thickness. The thickness is slightly less than fifty feet at Hill's mill; but in the Ne. ¼ of Sec. 20, Jefferson Tp., it exceeds seventy feet. The thickness of the Upper Maquoketa is approximately 150 feet. The thickness of the entire formation is much greater than has been heretofore reported; it varies from more than 200 feet in Mosalem township, to about 175 feet in the northwestern part of Jefferson. The relations of the several parts of the formation are shown in the following diagram:

Upper Maquoketa. 150 feet.	Transition beds, thin layers of impure, earthy dolomite.
	Plastic clay shales, with some indurated, fossiliferous bands near the top.
Lower Maquoketa. 50 feet.	Lean, fissile shales, with some earthy, non-laminated beds carrying Orthoceras and other fossils.

The lithological and faunal differences between the Lower and Upper Maquoketa, deserve more emphasis than they have yet received. The Upper Maquoketa, as has been said, is made up chiefly of plastic, unfossiliferous clays. These clays are well adapted to the potter's art. They weather more rapidly than the beds of the lower division, for which reason natural sections are exceedingly rare. They are seen at intervals in ravines leading down to the Little Maquoketa valley, north of Epworth. The Great Western railway has cut through beds of this horizon at a number of points both east and west of Kidder station. One of the best of the observed exposures of the Upper Maquoketa is found in a ravine in the Nw. ¼ of Sec. 27 and the Sw. ¼ of Sec. 22, Mosalem Tp. Between Julien and Peosta the Illinois Central railroad cuts through these upper beds at a number of points, but, owing to weathering and growth of sod, few of these sections are now satisfactory for study. The fossils of the Upper Maquoketa are found in thin, indurated, calcareous seams, well up towards the transition beds below the Niagara. The fauna is entirely distinct from that of the lower division. About a mile west of Kidder the fossiliferous slabs of this horizon are found in abundance on the sloping sides of the railway cuts, and the fauna here, as elsewhere, embraces such common Ordovician forms as branching monticuliporoids, *Plectambonites sericea*, *Orthis occidentalis*, *Orthis testudinaria*, *Rhynchotrema capax*, *Zygospira modesta*, *Tentaculites sterlingensis*, and *Ceraurus pleurexanthemus*. This fauna is essentially that of the Cincinnati shales of southwestern Ohio, and is not at all like that in the Graf and Hill's mill sections. *Plectambonites sericea*, *Orthis testudinaria* and *Ceraurus pleurexanthemus* were present in this area early in the Trenton; they seem to have disappeared from the region during the time represented by the later Galena and Lower Maquoketa; and then by migration they reoccupied these stations in Iowa, near the close of the Upper Maquoketa. The upper part of the Maquoketa, including the transition beds, is seen in the deep gorge known as Pine Hollow, in the northwest corner of the county, in Liberty township. The same beds, presenting the same characteristics, are seen at points along the Mississippi bluffs in the extreme southeastern part of the county, as well as in the hollows or gorges in the interior of Mosalem, the southeastern township. Reference has already been made to the exposures in sections 22 and 27 of Mosalem. It is in the Nw. ¼ of the Nw. qr. of Sec. 27, that the best section of the transition beds, noted during the progress of the present survey, occurs. Little more can be said of them than that the transition beds have a thickness of twenty-five feet; they are in non-laminated layers from two to six inches in thickness; they have a dirty, yellowish, clay color; and lithologically they are a rather soft, earthy or argillaceous, magnesian limestone. Fossils were not seen in these beds in Dubuque county, but at Rockville, a short distance over the line in Delaware county, the beds are well shown on the east side of the stream below the milldam, and here the lower layers contain *Orthis testudinaria.* These beds of passage, or transition beds, are everywhere overlain by the basal ledges of the Niagara.

SILURIAN SYSTEM.

NIAGARA LIMESTONE.

The Niagara limestone, which follows the Maquoketa shales, occupies a larger area in the county than all the formations so far discussed, taken together. The Niagara is the youngest of the indurated rock series known to be exposed within the territory under consideration. The eastern margin of its area is very digitate, owing to the effects of long continued, chiefly preglacial, erosion. The drainage of the sloping sides of the great river valley cut great gashes down through this formation and deep into the underlying strata, and left finger-like extensions of the Niagara limestone running out on the summits of the higher ridges. The Niagara is, in the main, a heavy, yellow or buff colored dolomite. In its general characteristics it resembles the Galena limestone, and in many cases it could not be distinguished from the Galena without a knowledge of its fossil contents or its stratigraphic position. The formation is, however, not homogeneous; it varies in character to some extent at different levels; and beds occupying the same stratigraphic level differ more or less at different localities. Beginning with the lowest ledges of the Niagara, in contact with the transition beds of the Maquoketa shales, the somewhat arbitrary divisions which, as a matter of convenience, were recognized in the field, are: 1, Basal beds; 2, Lower quarry beds; 3, Chert beds; 4, *Syringopora tenella* beds; 5, *Pentamerus oblongus* beds; 6, Cerionites beds; 7, Upper quarry beds.

The basal beds are seen at numerous points in the valleys of the Little Maquoketa and its branches; in the valley of Catfish creek; in Pine Hollow in the northwest corner of the county; and in numerous unnamed gorges and ravines in Mosalem and Table Mound townships. The west end of the

Fig. 51. Train of blocks from the basal portion of the Niagara limestone creeping down slope occupied by Maquoketa shales. View taken in section 36, Iowa township.

dam at Washington Mills, in the southeast corner of Prairie Creek township, rests against characteristic ledges of the basal beds. At all points where these beds were seen in Dubuque county they consist of heavy layers, four to six, or even more, feet in thickness. As noted in the report on Delaware county, Volume VII of the present series of reports, the basal beds tend to split along lamination planes into relatively thin slabs. In general, however, the cohesion of the laminæ is so strong that masses of many feet in thickness retain their integrity even after undergoing tilting and displacement by reason of undermining brought about by weathering of the softer Maquoketa.

On all the gentle declivities occupied by the Maquoketa shales, between the Niagara escarpment and the top of the

Galena, great masses of the basal division of the Niagara, twelve feet or more in thickness, and not infrequently forty to fifty feet in length and as many in width, are seen in all positions gradually creeping down the long slopes. From year to year they come, inch by inch, as the insecure, mobile, slippery foundation gives way beneath their enormous weight. In places they occur in trains; very old, weathered blocks in the lead, with fresh, unweathered masses, but lately detached as a result of undermining, bringing up the rear. A part of such a train, half way down the slope, some of the blocks on edge and some in other positions, is shown in Figure 51, from a view taken in the Sw. ¼ of Sec. 36, Iowa Tp. In the Nw. ¼ of Sec. 21, Center Tp., there is a large mass of basal Niagara lying in the bed of the Little Maquoketa, at the base of a cliff of Galena limestone sixty feet in height. Here is a block which crept down the whole length of the Maquoketa incline and, at the bottom, tumbled over a sixty-foot cliff of Galena without undergoing complete destruction. The fact that some of these masses, which may attain dimensions of 100 feet or more, settle down without disturbing their horizontal position, adds to the difficulties of the geologist by presenting the deceptive appearance of native ledges of rocks in place. Still another source of error is found in the tendency of the soft, plastic, slippery beds of the Maquoketa to flow out, along steep hillsides, under the weight of the Niagara, and allow a body of limestone some scores of feet in thickness, and a half mile, or a mile, or even more, in length, to settle evenly without apparent displacement. An example of the bodily settling of what seems to be the whole mass of the Niagara, occurs along the Illinois Central railway, about a mile and a half northeast of Peosta. In the Se. ¼ of the Ne. qr. of Sec. 3, Vernon Tp., the railway at one point cuts through Maquoketa shales at a depth of seventy feet below the contact with the Niagara; and only thirty rods to the southwest, without essential change of level, the track enters a cut in the lower quarry beds of the overlying limestone. A mass of Niagara of unknown length, and fully 100 feet in thickness, has here been allowed to settle, on account of flow of the soft shales, through a vertical distance of not less than eighty feet. This behavior of the Niagara whereby portions, particularly of the basal layers, are displaced without affecting their horizontal position, will probably account for the fact that Hall assigned to the underlying shales a thickness of less than seventy-five feet, and White a thickness of only eighty feet.

The characteristics of the Niagara as a whole, as well as of its several divisions, will be best understood by the consideration of a few typical sections. On the land of Z. Kidder, in the Sw. ¼ of Sec. 2, Taylor Tp., a small quarry has been opened in a situation which shows, in descending order:

	FEET.
5. Chert beds consisting of coarse-grained dolomite in very uneven, thin layers, interbedded with a large amount of chert	4
4. Lower quarry stone in courses varying from eight inches to two feet in thickness; stone light-gray to cream color, rather fine-grained, the upper layers carrying more or less of chert	14
3. Basal beds in heavy layers which are, however, capable of being split along lamination planes into relatively thin divisions	12
2. Transition beds of Maquoketa	13
1. Plastic shale of the Upper Maquoketa; not measured.	

In the Nw. ¼ of the Sw. qr. of Sec. 36, Iowa Tp., there is a small quarry which shows:

	FEET.	INCHES.
6. Coarse, worthless dolomite in very uneven and thin beds, interstratified with a large amount of chert; chert equaling or exceeding in volume the dolomite, broken into small, angular fragments; lower part of chert beds	12	
5. Quarry stone in single course; with many nodules of chert	1	
4. Moderately good ledge with some chert, caps into three or four layers	2	11
3. Cherty, rather worthless ledge, a single course.	1	2
2. Ledge of good quarry stone	2	4
1. Good quarry stone	0	10

At the railway cut in the southeast quarter of section 3, Vernon township, in the great settled block of Niagara previously noted, the chert beds, with a thickness of twenty feet, are exposed in the upper part of the section, while the lower part shows ten feet belonging to the lower quarry beds and

Fig. 52. East Farley quarry showing the characteristics of the Lower Quarry beds of the Niagara limestone.

made up of courses ranging from three to fourteen inches in thickness. A few rods southwest, in the next quarter section, there is an opening showing the top of the quarry beds, above which the full thickness of the chert beds, twenty-five feet, is exposed. Near the base of the second member of the section at this locality there is about as much chert as limestone; farther up the limestone furnishes some usable layers, but the bedding surfaces are very uneven, and the limestone courses are still separated by very pronounced seams and nodules of chert. Above the chert beds at this point there are eight feet of coarse dolomite containing colonies of *Halysites catenulatus* and *Syringopora tenella*. On all the slopes on both sides of the valley, followed by the railroad in sections 3 and 10 of Vernon township, the coarse, imperfectly bedded and practically useless beds of the *Syringopora tenella* zone are exposed above the chert beds up to the top of the bluffs.

The quarries in the vicinity of Farley illustrate well the characteristics of the lower quarry beds. The East Farley quarry (Fig. 52), worked by P. A. Milesi, is located in the southwest quarter of section 8, Taylor township. It affords the following section:

		INCHES.
8.	Coarse-grained bridge stone	21
7.	Stone of medium grade	28
6.	Ledge of fine-grained stone, with some chert	24
5.	Stone similar to number 6	14
4.	Fine-grained stone of good quality	4
3.	Stone of same quality as number 4	17
2.	Stone similar to 3 and 4	9
1.	Stone like 2, 3 and 4	26

Over the quarry stone there occurs, as waste or stripping, from one to three feet of decayed ledges, a foot or two of dark-colored residual clays which carry a large amount of chert, and three or four feet of drift and loess. Numbers 1, 2, 3, 5 and 6 furnish a good grade of dimension stone. The stone cuts easily, is fine-grained, light gray to light buff in color and tinged in places with streaks of iron oxide. Number 7 is worked for bridge stone.

The North Farley quarries are owned and operated by Mr. B. N. Arquitt. They are located in the southeast quarter of section 6, Taylor township, and have been worked more or less continuously for forty years. The several courses here are essentially the same as at the East Farley quarry. Certain courses which are single in one part of a quarry may be divided elsewhere, and layers which may be "capped" are estimated as single courses in one place, and as two or more separate courses in another. The usable quarry layers at the Arquitt quarries are overlain by three or four feet of residual clays and cherts, below which are four to twelve feet of decayed chert beds, and a solid, cherty ledge three and a half feet in thickness. The quarries are equipped with a number of derricks, the usual quarrying tools, horse-power hoists, and steam sawing and rubbing machinery. The courses quarried below the stripping are:

		INCHES.
9.	Thick course used for cellar rock and rip-rap	36
8.	Heavy course used for bridge rock	24
7.	Bridge rock	24
6.	Bridge rock	16
5.	Cherty layer, furnishes some good material	18
4.	Coarse, cherty in places, but sometimes furnishes very good stone	14
3.	Coarse with some chert, used for cellar walls	12
2.	Stone of excellent quality, easily sawed to requisite dimensions	16
1.	Bottom ledge of good quality, caps along certain planes, easily sawed	26

As in all other exposures of the lower quarry beds, the courses are here separated by shaly partings, and the stone is a soft, easily worked, light-colored dolomite. The present demand for bridge stone taxes the output of the heavier layers, but were the conditions of the market different, numbers 6, 7 and 8 could be easily worked into rubble and dimension stone. The full thickness of the chert beds is developed in the hills which rise above the quarries to the southward.

The beds of the lower quarry horizon are exposed at so many points that it would be unprofitable to refer to them all. They may be seen and studied wherever erosion has revealed this part of the geological column, whether in the bluffs and walls of the ravines of Mosalem and Table Mound townships, or in the charming and picturesque gorge in the northwest part of Liberty. The beds increase in thickness toward the northwest, but remain constant as to other characteristics. The quarries near New Vienna, in sections 5 and 9 of New Wine township, utilize the lower quarry beds. As compared with the more thoroughly dolomitized and crystalline strata of the Syringopora and Pentamerus zones, the beds of the lower quarry zone weather easily, for which reason they are rarely exposed in the natural cliffs. Furthermore the overlying chert beds break down quickly under the effects of the weather, the sharp, angular fragments to which the chert layers are reduced constituting a large amount of indestructible talus material which effectually conceals the soft, evenly bedded quarry stone. It so happens, therefore, that it is only under somewhat unusual and very favorable conditions that the lower quarry stone is naturally revealed at all; but any one interested in quarry development can easily locate the zone desired and expose the layers by stripping away the waste material by which they are concealed.

On the west side of Lytle creek at Washington Mills, in section 36, Prairie Creek township, there are exposures in the hillside which, though not continuous, indicate clearly the order of superposition of the lower members of the complete Niagara section. Below the milldam a large spring issues in the bottom of the valley, at about the level of the water in the creek. In Clayton, Delaware and Dubuque counties springs are common near the line of contact between the Niagara limestone and the Maquoketa shales. The descending waters, stopped by the shales, flow out at the lowest point below their head at which they can find exit, in some cases above, and in others below the line referred to. This spring is almost at the exact level of the contact line. The west end of the mill dam at this point abuts against basal beds of the Niagara, which show fully twelve feet in thickness. The top of the basal beds forms the floor of a quarry which is worked a little higher up on the hillside and exposes sixteen feet of fairly regularly bedded quarry stone, the lower quarry horizon. Above the quarry stone, as usual, are beds rich in chert; but the thickness of the chert beds could not be definitely determined, owing to the fact that the slopes are covered with soil and other loose materials. Fifty feet above the stream there are outcropping ledges of coarse, crystalline dolomite suitable for lime burning, containing fine colonies of *Syringopora tenella* and *Halysites catenulatus*. The corals named continue up to an altitude of eighty feet above the creek; at ninety feet the beds contain *Lyellia americana* in place; and immediately above the ninety-foot level the rocks contain casts of *Pentamerus oblongus.*

Near the northeast corner of section 22, Washington township, there are projecting ledges of Niagara containing *Syringopora tenella, Halysites catenulatus, Favosites favosus, Lyellia americana*, and an unnamed species of Lyellia with small visceral tubes. On the hillsides there are loose slabs containing *Pentamerus oblongus.* In the Sw. ¼ of the Nw. qr. of Sec. 27, Mosalem township, near King postoffice, the road follows a ridge from the crest of which the surface descends in both directions to the bottoms of ravines 180 feet in depth. On the steep slopes there are rock exposures containing Syringopora and Halysites at an elevation of 100 feet above the base of the Niagara, and a few loose fragments of limestone, near the top of the ridge, contain casts of Pantamerus. The crags projecting from the sides of Table Mound, as well as the undisturbed layers on the summit, contain Syringopora and Halysites; while in loose fragments, on the very crest of the mound, there are occasional casts of Pentamerus. The point is that in southeastern Dubuque county there are usually not less than 100 feet, and in some cases at least 125 feet, of Niagara below the true Pentamerus horizon. The *Syringopora tenella* zone includes a thickness of forty-five or fifty feet between the chert beds and Pentamerus beds, the name being derived from the most typical coral of this horizon. Along Elk creek, in Delaware county, the lower members of the Niagara have a greater thickness* than in the central and southeastern parts of Dubuque. Furthermore, the chert beds, if they exist there, are concealed, and the space they occupy was added, in the Delaware county report, to the *Syringopora tenella* beds.

Near the southwest corner of section 32, White Water Tp., there are prominent crags and vertical cliffs of Niagara which yield the following section:

*Geology of Delaware county, Iowa Geol. Surv., Vol. VIII, p. 148. Des Moines, 1898.

		FEET.
11.	Light-colored, fine-grained rock resembling the upper quarry beds	2
10.	Soft, yellow, easily decomposed dolomite; Cerionites beds	4
9.	Moderately hard, yellow dolomite, with *Cerionites dactylioides*, *Caryocrinus ornatus*, *Eucalyptocrinus crassus*, *Pentamerus pergibbosus* and *Bronteus laphami*	5
8.	Soft, fine-grained, gray dolomite; Cerionites beds	15
7.	Coarse, massive dolomite, standing in vertical cliffs; *Pentamerus oblongus* horizon	45
6.	Hard, very compact dolomite, with many casts of Pentamerus, and some chert	5
5.	Soft, rapidly weathering, light-gray beds, with *Pentamerus oblongus* and non-silicified corals	2
4.	Moderately soft, rapidly weathering dolomite, containing the same corals found in number 3	7
3.	Hard, dark-gray beds, with many colonies of *Favosites hisingeri*, *Halysites catenulatus*, *Syringopora tenella*, and *Heliolites interstinctus*; all the corals are silicified; a good lime-burning rock	8
2.	Coarse, granular, light-buff dolomite, weathering irregularly and showing definite bedding planes; silicified corals, as in number 3	20
1.	Slope to level of water in stream, rock not exposed	20

In the above section numbers 2 to 4 belong to the *Syringopora tenella* beds; numbers 5 to 7 represent the zone of *Pentamerus oblongus*; 8, 9 and 10 are the Cerionites beds; and number 11 may possibly represent the upper quarry horizon. A short distance west of the cliff described, near an old limekiln, the Cerionites beds are exposed at the same level as in the cliff. Here they contain Favosites like *F. favosus*, *Caryocrinus ornatus*, a species of Stricklandinia, *Ambonychia acutirostra*, a slender, elongate Murchisonia, a large Straparollus, the annulate siphuncles of Oncoceras, and *Bronteus laphami*, besides the typical species, *Cerionites dactylioides*. A few rods southwest of the old limekiln referred to there is a large quarry opened in the hillside. The face of the quarry extends for a distance of 300 feet, and it exposes a section of about twenty feet. Beds 5 and 6 of the detailed section run through the middle of the quarry, the casts of *Pentamerus oblongus* being exceedingly common. The stone is of medium quality, the layers ranging from four to twenty inches in thickness. About a mile west of the points just described, in the bank of the river below the mill at Cascade, there are ten feet of beds corresponding to number 2 of the section last described, below which are six feet belonging to the chert beds. The mill is located at a natural fall in the North Maquoketa river. Above the falls the floor of the channel is made up of a few feet of the rather hard, crystalline beds of the Syringopora zone. The underlying chert beds tend to weather and crumble and recede faster than the harder and purer dolomite above them; and thus there is brought about here, on a modest scale, the conditions of resistant beds underlain by rapidly crumbling strata, on which falls in streams so generally depend.

In section 36, White Water township, White Water creek flows in a steep-walled gorge 170 feet in depth. Near the bottom of the gorge and coming down to the level of the water in the stream, there are heavy, crystalline, hard beds containing *Halysites catenulatus*. Steep, inaccessible cliffs alternate with sodded slopes up to a height of 145 feet above the water, in which space are included the upper part of the Syringopora zone and all of the Pentamerus and Cerionites beds. One hundred and forty-five feet above the stream there is a small opening in the upper quarry beds from which quite an amount of valuable stone has been taken. The rock is evenly bedded in layers three to eight or ten inches in thickness, fine grained, cream to light buff in color, and contains the flat variety of Pentamerus which is characteristic of this horizon. The stone used in building Saint Martin's church at Cascade, was taken from this quarry.

In sections 31 to 36 of Cascade township, there are numerous exposures which repeat at varying heights the members of the section seen east of Cascade, in section 32 of White Water township. Along the stream in the Ne. ¼ of Sec. 30, Cascade, there are cliffs forty feet in height, embracing parts of the same section. At Hillside mills in section 18, the valley of the Maquoketa river is 150 feet deep, and the rocky cliffs in the walls of the gorge show Pentamerus and Cerionites beds almost up to the level of the upper quarry horizon. A small quarry is opened in these upper beds in the Se. ¼ of Sec. 15, Cascade Tp., on land of P. Kremer; another quarry at the same horizon is located on land of J. Gearhart, in the Sw. ¼ of Sec. 4; and there is still another in the upper quarry beds near the northwest corner of section 5. In all the quarries in the central and northern part of Cascade township, a large proportion of the stone is thin-bedded and suitable for flagging; but there are not wanting heavier courses ranging from ten to fourteen inches in thickness to furnish desired material for all grades of range and rubble work.

A short distance from Dyersville, in the Se. ¼ of Sec. 32, New Wine Tp., there are quarries which work thin-bedded limestone more suitable for flagging than for any other purpose. The beds are unfossiliferous; a few decayed specimens of *Ptychophyllum expansum* were, however, seen in the refuse. There is another quarry in coarser and thicker beds, about the middle of the line between sections 5 and 6, Dodge township. The last quarry is probably below the level of the thin, flagging stone near Dyersville. The stratigraphic relations of the beds at the two points mentioned can not be made out, and owing to this fact, and to the absence of diagnostic fossils, it is not possible to state definitely the horizon to which they belong. It is probable, however, that they are part of the Syringopora zone. For in the northern part of the county, as, for example, near Balltown, Jefferson township, the chert beds are followed by ten feet of limestone in rather heavy layers, above which there are eight to ten feet of thin-bedded material like that in the quarries near Dyersville. The thin beds are more resistant than the heavier beds below, and in weathered cliffs they form projecting cornices as shown in Figure 53. The presence of flagging beds in the position they occupy in Jefferson township, together with the specimens of Ptychophyllum referred to above, supports the conclusion that the Dyersville quarries are in the Syringopora horizon.

This conclusion receives further support in the fact that there is a small quarry working somewhat similar material known positively to belong to the Syringopora beds, in the Sw. ¼ of the Ne. qr. of Sec. 27, New Wine Tp.

The outcrops of the Niagara in the beautiful gorge of Hollow creek, in the northwest corner of Liberty township, give rise

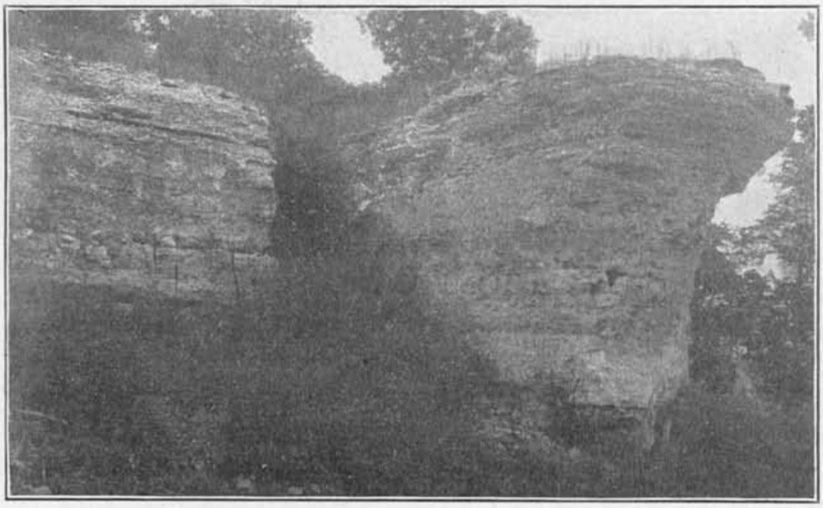

Fig. 53. View taken near Balltown in Jefferson township, showing, in the upper part of the cliffs, the flagstone beds of the *Syringopora tenella* zones.

to many picturesque castles and towers and flying buttresses which afford keen delight to all visitors who are capable of being impressed with natural grandeur. A short distance south of the north county line the sides of the gorge rise almost vertically for 300 feet, and a gentler slope carries the rim fifty feet higher. The base of the Niagara is here about 125 feet above the bottom of the valley, and well up the sides there are unscalable, vertical cliffs of the massive dolomite, eighty feet in height.

Exposures of Niagara limestone are very numerous throughout all the area west of the Niagara escarpment. Those above noted have been chosen for record simply because each is typical of many others, and all together they afford a comprehensive view of the Niagara as a whole. A few specific cases of characteristic outcrops, not included in the general conspectus given in the foregoing pages, may still be worthy of mention. Northwest of Epworth, a ravine which nearly coincides with the line between sections 10 and 11 of Taylor township, shows, in descending order, the chert beds, lower quarry beds and basal beds of the Niagara, together with transition beds and plastic clay beds of the Upper Maquoketa. The basal and quarry beds are exposed along Lytle creek, near the northwest corner of section 29, Washington township, while chert beds overlain by some thin flagging occur one-half mile east of the creek. In the Nw. ¼ of Sec. 21 of Washington, there are exposures of massive Niagara belonging to the Pentamerus beds. At this point the shells of the Pentamerus are partly preserved, a somewhat unusual occurrence in dolomitic limestone. This phenomenon has been noted elsewhere in Iowa in only a few instances, the most striking example being found in the quarry east of Earlville in Delaware county. Associated with the Pentamerus in Washington township are *Favosites hispidus*, *Halysites catenulatus*, and *Heliolites megastoma*. Along Curran creek in section 35, Taylor township, there are high cliffs of Niagara embracing the upper part of the Syringopora, and the lower part of the Pentamerus beds. The rock is here imperfectly dolomitized, very coarse, irregularly bedded, and much weathered in pits and seams as now exposed. Fossils are scarce, but *Halysites catenulatus*, *Cannapora annulata*, *Heliolites interstinctus*, and *Pentamerus oblongus* were observed. The massive, coral-bearing beds of the Syringopora zone, with Halysites and other typical genera, are quarried a few rods south of the Dubuque county line, in the valley of the small creek west of Zwingle. The same beds crop out north of the road, in Dubuque county. A very coarse-grained rock containing small colonies of Halysites occurs in the walls of gorges cut by branches of Lytle creek, in section 33 of Table Mound township. In the Se. ¼ of Sec. 30, Iowa Tp., on land belonging to Mr. J. H. Tutt, there are a number of good exposures showing Pentamerus beds with a thickness of nearly forty feet, below which are hard, heavy, crystalline strata of excellent qualilty for lime-burning. These lower rocks have the bedding planes largely obliterated and show in a typical way the characteristics of the thoroughly dolomitized portions of the Syringopora zone.

From the field notes and observations on which the foregoing descriptions are based, the following generalized summary of the Niagara section may be deduced:

		FEET.
7.	Upper quarry beds	20
6.	Cerionites beds	25
5.	Pentamerus beds	50
4.	Syringopora beds	65
3.	Chert beds	25
2.	Lower quarry beds	20
1.	Basal beds	15
	Total thickness of the Niagara limestone in Dubuque county	220

SUPERFICIAL MATERIALS.

In Dubuque county, as in nearly all other portions of the land surface of the globe, the indurated rocks are overlain by loose, unconsolidated materials which are products of rock disintegration. These loose materials constitute the soils and subsoils of the region in which they occur. They differ among themselves very greatly in respect to their history and genesis. Some were produced in the exact places where they are now found, by the slow, atmospheric decay of rocks similar to those upon which they lie. In many cases the soil materials have been produced by the disintegration of rocks in localities remote from the places they now occupy. They may have been transported for longer or shorter distances by flowing water, by moving ice, or by the action of the wind. Transported they have been in some way or other. The untransported soils, the soils formed in place, are made up of:

Residual Materials or Geest.—Through the chemical and mechanical action of air and water all exposed rocks are, and ever have been, undergoing a process of slow decay. The work of rock disintegration is hastened by the presence of carbon dioxide, or other active adventitious gases in the air; or of the organic acids produced by decay of organic matter in the waters with which the rocks are in contact. The product of rock decay is an assemblage of incoherent particles of various sorts, which may accumulate by the progressive downward action of the process to depths of many feet. All the soluble constituents of the rocks which have suffered destruction, are likely to be carried away by the percolating waters, and the remaining insoluble, *residual* materials not infrequently undergo complete chemical and mineralogical change. For these reasons the resulting products quite generally bear little resemblance to the rocks from which they were derived. The different kinds of residual products seen in Dubuque county will presently be noted. These products are not assigned to any definite geological age, for the reason that rocks have been decaying, and residual materials have been forming ever since the county, at the close of the Silurian or early in Devonian time, rose above the sea.

In the county under consideration the residual materials derived from the decay of either the Saint Peter sandstone, or the Trenton limestone as limited by the definition of the Trenton on preceding pages, are small in amount and need not be here discussed. The residual products of the Galena limestone take the form of very dark brown or red, ferruginous clays which may be mixed with more or less of chert. But little of the Galena residuum, however, is seen at the surface. The formation has contributed only an inconsiderable amount of material in this county to the formation of soils, and that for the reason that the Galena is not here a surface rock over any very large area. But underground, where some might think it was protected from the atmosphere, it has been eaten away by the agents of rock disintegration; great caverns have been formed by destructive waste; and the brown, or red, or ocherous clay found in the crevices, and known as "crevice drift," is the resulting product. Of this product but little could have been known but for the conditions which have led to the exploration of every fissure and cavern, so far as they have been located, in the search for mineral wealth.

The largest areas in the county in which the Galena may be regarded as the surface rock, occur in the valley of the Little Maquoketa and its branches, in Dubuque, Peru, Center, and Jefferson townships; and here there are occasional exposures of dark, ferruginous, residual clays among the constituents of the superficial materials. A good illustration is found in one of the railway cuts, a mile and a quarter northeast of Graf, where dark brown geest, to a thickness of three or four feet, is seen resting on weathered and partly decayed Galena. In the city of Dubuque, on Wood street, west of West Fourteenth, there is a bed of very dark residual clay, three feet in thickness, lying on the Galena and overlain by six feet of yellowish loess.

The residuum from the Maquoketa is the product of weathered shales. It is a clay differing less than is usual with residual materials from the beds from which it has been derived, and forming the inorganic part of much of the soil and subsoil of the region in which the Maquoketa formation occupies the surface.

The most extensive and the most conspicuous body of residual materials in Dubuque county is that which has been derived from the Niagara limestone. It forms an almost continous sheet over the whole of the large area in which the Niagara is the formation of indurated rocks lying nearest to the surface. While within this area, residual materials have doubtless been carried from the surface, along crevices, to great depths, and while they must have been produced, as in the case of the Galena, by waste and decay resulting from the widening of fissures and the formation of underground caverns, the body of such materials, which we know from actual observation, lies on top of undecayed Niagara and usually underneath beds of loess and drift. The residual products of the Niagara consist of dark, ferruginous clays with which is usually mixed a greater or less amount of chert reduced to angular fragments. In localities where the chert beds—number 3 of the general Niagara section—have suffered disintegration, the residuum consists of a small amount of clay filling the interstices of chert fragments packed together as closely as the pieces of broken stone in a macadamized street. Where roads traverse such an area they are provided with a natural macadam, an example of which occurs in the northeast quarter of section 35, Center township. Other examples of the same kind are by no means uncommon, and exposures of geest derived either from the chert beds or from portions of the formation containing less siliceous material, are almost as numerous as sections of the superficial deposits showing contact with the underlying Niagara limestone. At one or two points in section 21 of Concord township, the residual clays and cherts of the Niagara attain a thickness of six feet, and a similar bed, three feet in thickness, occurs near the center of section 16, Vernon township.

During the very long interval between the elevation of Dubuque county above sea level, and the advent of the glacial conditions which spread a mantle of drift over almost the entire surface of Iowa, the exposed Niagara limestone suffered decay to an extent which cannot now be fully determined. The loose products resulting from this decay, however, were subject to the effects of erosion, and a very large proportion of them was carried away by flowing water. With the oncoming of the glaciers, which transported and distributed the first sheet of drift, such residual products as still remained upon the surface were more or less disturbed, and their materials, to a certain extent, were worked up and mixed with the detritus carried by the moving ice. Still it is true that the glaciers which passed over the surface left the old residual products intact to an extent which, to any observer, is a constant source of surprise.

PLEISTOCENE SYSTEM.

KANSAN DRIFT.

The Kansan drift is the oldest of the Pleistocene deposits positively recognized in Dubuque county. In the remarkably interesting and complete series of well records gathered by McGee* as a result of years of energetic research, there are some indications of a pre-Kansan drift. For example, a well located in the Se. ¼ of the Nw. qr. of Sec. 21, Iowa Tp. (well 67, p. 522 of the work cited) is recorded as showing: "Loess, six feet. Coarse yellow clay slightly assorted above, four feet. Soft tenacious blue clay, twelve feet. Dark soil containing woody fragments and ferruginous nodules, with a marshy odor, two feet. Finer tenacious blue clay with a few pebbles, eight feet. Water flowed in from the forest bed, and was so foul that the well was abandoned." The above record admits of the following possible interpretation: The coarse yellow clay beneath the loess, weathered Kansan. The twelve feet of soft blue clay which follows, unweathered Kansan. The soil with woody fragments and marshy odor, horizon of Aftonian forest bed. The lower eight feet of tenacious blue clay, pre-Kansan drift. Similar records indicating the existence of a sheet of till or bowlder clay beneath a definite soil or forest bed, are presented by wells numbered 86, 90, 97, and 113 in the work referred to. If more extensive sections than those afforded by isolated wells were available for study, it is possible that the facts might require some different hypothesis for their explanation; but the well records referred to are perfectly consistent with sections in the interior of the state, which very strongly indicate the existence of a till older than the Kansan, and separated from the Kansan by a time interval sufficient to permit of the growth of forests and the development of a well defined band of soil.

The sheet of till which geologists in recent years have been

*Pleistocene Hist. of Northeastern Iowa, by W J McGee. Eleventh Ann. Rep., U. S. Geol Sur., pp. 521-528. Washington, 1891.

agreed in calling Kansan, is, at all events, fairly well developed over all the portion of the county lying west and southwest of the margin of the driftless area. The Kansan drift is usually overlain by loess. Normally, beneath the loess, it shows (1) a weathered zone ranging up to six or eight feet in thickness, much oxidized and sometimes quite ferruginous, reddish or brownish near the upper surface, but becoming yellow at no very great depths; and (2) blue, unaltered till, the thickness of which depends on the amount of drift present at the point under observation. The yellow zone may blend somewhat gradually into the blue; and narrow, yellow, weathered bands may descend along joints in the blue till to depths of ten or fifteen or twenty feet. The unaltered, blue Kansan is usually quite calcareous, but in the upper part of the oxidized zone calcareous material is absent, the normal lime constituent having been removed by long exposure to the weather. The surface of the Kansan drift in Dubuque county had suffered the usual amount of erosion before the deposition of the loess. Complete drainage was developed, and this involved the carving of a dendritic system of water courses which branch and re-branch, and finally terminate on the higher uplands, in shallow draws, broadly V-shaped in cross section. The profile of such a surface consists of a series of convex curves, with the summits of the swells, at a distance from the larger drainage courses, rising to the level of the original undulating surface of the drift as it was left when the glaciers which deposited it retreated. The topography of the Kansan area, essentially as the surface appears at present, was fully developed before the loess was laid down; for this later deposit forms a relatively thin sheet more or less evenly spread over an erosion-carved system of hills and trenches which, if the loess were stripped off, would depart but little from the contours and reliefs of the present surface.

The Kansan till seems originally to have been a tenacious blue clay carrying a large amount of powdered limestone. The upper zone, however, has been altered in color; oxidation and weathering have developed the reds, and browns, and yellows which now distinguish it. The zone has also been altered in composition; by the leaching effect of descending ground waters it has lost its calcareous constituent. In both the altered and unaltered Kansan, limestone pebbles and nodules are not uncommon. Northern bowlders are numerous, but they rarely attain a size exceeding two or three feet. There are some granites, and many of these, in the weathered portion, have become softened and decayed. Greenstones are common; and striated greenstone bowlderets may be regarded as among the most characteristic constituents of the Kansan till. Quite as interesting and almost as characteristic are the battered, frayed and splintered fragments of trees, which are distributed promiscuously throughout a thickness of many feet in the lower part of the drift sheet we are considering. The land, prior to the advent of the Kansan ice, was heavily forested; and the forest material, crushed and broken and abraded by resistless glaciers, was worked up into the drift and mingled with the waste and ruin of countless rocky ledges over which the ice sheet had passed. The old soils and humus beds of the pre-Kansan forests were very frequently left undisturbed, as is nowhere better shown than in McGee's splendid series of well sections previously noted.

The eastern margin of the Kansan drift is approximately indicated on the Pleistocene map which accompanies this report. That the line marking the boundary between the drift and the driftless area is absolutely correct, is not claimed; but, in general, it does not deviate from the extreme position occupied by the edge of the Kansan ice by more than one mile. Along the line referred to, the topography undergoes an abrupt change. On one side there is the eroded drift plain, with miniature hills and valleys cut in loose, superficial materials, just such a plain as characterizes the Kansan area throughout all the southern part of the state; on the other side are the deep trenches cut in indurated rocks, and all the other topographic forms and features of the driftless area. The

Kansan drift is greatly thickened toward its margin, forming a sort of morainic belt, which has, however, been much softened and subdued by long-continued erosion. The best opportunity to see the thickened margin is in the railway cut a short distance east of Peosta. Here there are at least thirty feet of typical Kansan till, blue and unchanged toward the base of the cut, but showing the effects of weathering near the original surface. This thickening of the drift at the margin gives rise to a fairly well defined ridge from which the surface slopes both ways. The descent to the driftless area is abrupt, and is accomplished in a short distance; that to the westward is more gentle, and the slope eventually blends imperceptibly into the general Kansan plain. By reference to the map it will be seen that the drainage of this part of the county is, on both sides, away from the marginal ridge.

The thickness of the Kansan drift is very variable. At many points west of the margin, in some cases within less than a mile of the thick morainic ridge, the trenches and rain-washed gullies in fields and along waysides show no trace of drift, except probably a few pebbles of crystalline rocks mixed with the local cherts and residual clays. The loess rests directly on residual materials. On many of the slopes within the Kansan area, both till and loess, if they were ever present, have been removed by erosion, leaving only some small northern bowlders to indicate that an ice sheet had ever occupied the region. Kansan till impresses itself on the observer following the ordinary wagon roads, at scores and scores of points where recent rainwash has cut through the overlying loess. As seen under such conditions the ordinary aspect is that of a very red, ferruginous, pebbly or sandy deposit. It is only the most altered upper part of the formation which is thus seen. The effects of long pre-loessial exposure to the atmosphere is expressed in the removal of the fine clay from the superficial zone and the segregation of the coarser sand and pebbles, as well as in the processes of ferrugination, oxidation, and leaching which have been previously noted.

Buchanan Gravels.—While the Kansan ice was melting away, and torrents of water flowed out over the recently bared surface of the drift which the ice relinquished as it receded, large quantities of clay, sand, and gravel were carried by the turbid floods and deposited along the drainage courses where, for any cause, the impetus of the currents received the necessary check. The materials so carried and deposited were sorted in accordance with the laws governing transportation and deposition by flowing water, and the beds into which they were finally built up were more or less regularly stratified. In the latitude of Dubuque county and northward the accumulations referable to this particular episode in the history of glacial conditions, are composed of coarse materials, largely of gravel mixed with quantities of sharp quartz sand. From their great development in Buchanan county, these accumulations have been called the Buchanan gravels. Buchanan gravels are among the conspicuous Pleistocene deposits of the county we are now considering.

Owing to their permeability to air and moisture, the Buchanan gravels are usually very much weathered and oxidized; and they are sure to attract attention by reason of their red tints and rusty ferruginous appearance near the surface. Cross-bedding is one of the common characteristics of the deposits, which, together with the coarse nature of the material, is indicative of deposition from strong currents. A few rods south of the postoffice at Peosta, the wagon road cuts through a low ridge which shows from two to four feet of rusty beds of water-laid sand and gravel of Buchanan age, overlain by four feet of loess; and on the eastern slope of the thick marginal ridge of Kansan drift, three-fourths of a mile east of Peosta, there is a very typical bed of these gravels on the south side of the railway track. A bed of the gravel, rather sandy and somewhat modified by erosion, is seen a rod or two south of the railway crossing, near the station at Epworth. A short distance northwest of Epworth, in the Sw. ¼ of the Nw. qr. of Sec. 10, Taylor township, sixty feet below the level of the railway track, recent erosion has cut a deep gully in stratified sands and gravels of this age. This last exposure is somewhat unique in the fact that a part of the water-laid deposits here associated with the Buchanan gravels is a fine drab clay. There are two layers of the clay separated by a band of reddish sand. Usually the finer silts transported by the muddy streams from the melting Kansan ice were not deposited within the limits of the territory under investigation. They were carried farther southward, but the beds to which they have given rise have not yet been specifically recognized. Another exposure of the gravels in Taylor township occurs about one-fourth of a mile south of the northwest corner of section 3. In Cascade township exposures of Buchanan gravels are not uncommon. It will be sufficient to mention a pit worked quite extensively for road material a short distance northeast of the center of section 16, another a short distance north of the southeast corner of section 22, a fine exposure in the southwest part of 22, and another near the center of section 28. The gravel bed in section 16 is a part of a low ridge rising slightly above the surrounding surface; it is worked to a depth of six feet, is very ferruginous and rusty, shows the bedding planes well, and includes, with pebbles of foreign origin, a considerable amount of local chert. Gravel ridges of the kind described are met with occasionally; they may represent kames or eskers instead of an outwash from the margin of the melting ice. Other occurrences of the gravels simply repeat the phenomena already described.

Kansan Outwash in the Driftless Area.—Within the driftless area, well out from the margin of the Kansan drift as this is traced on the accompanying map, there are occasional Kansan bowlders from a few inches to a foot or more in diameter, together with accumulations of ferruginous materials resembling the Buchanan gravels. Some of the bowlders and gravel deposits are found on comparatively high ground; but, most naturally, the outwash from the Kansan ice margin followed the drainage courses. A Kansan bowlder, ten or twelve inches in diameter, lies by the roadside, on a high plateau, in Mosalem township; and there is quite a large body of ferruginous, gravelly material, with cobblestones of Kansan type, on the comparatively high ridge followed by the road in Dubuque township, a short distance east of Julien. Near Table Mound, in the Sw. ¼ of Sec. 11, Table Mound Tp., there are numerous pebbles of northern, crystalline rocks mingled with the thin layer of residual materials underneath the loess. In general, however, the Kansan outwash is to be sought in the valleys of such streams as head well up toward the Kansan margin. Trains of gravel and bowlders seem to have been strewn along the Little Maquoketa valley from a short distance below North Farley to the mouth of the stream, but only a few remnants of these deposits have escaped subsequent erosion. The valley of Catfish creek has some deposits of this age, and so has the valley of Grange creek. In the valley of Grange creek, in the Ne. ¼ of Sec. 23 and adjacent parts of 13 and 14, Table Mound Tp., there is quite a large deposit of very characteristic Kansan material.

The time of transportation and deposition of the outwash referred to probably coincided with the time of maximum development of the Kansan ice. The streams of the driftless area at this time afforded the only outlet for the drainage waters resulting from the continual ablation of the ice, and the same conditions must have persisted for some time after rapid melting and actual retreat of the glaciers began. These eastward sloping valleys were accordingly taxed to their capacity with turbid floods; and sheets of water, loaded with detritus from the Kansan drift, doubtless flowed out over even the higher levels before being gathered into definite streams. Pebbles and well rounded bowlders are known, in many instances, to have been carried for long distances by simple sheet water action, and the presence of outwash in even the higher parts of the driftless area need excite no surprise.

IOWAN DRIFT.

The interval which followed the withdrawal of the Kansan ice and the deposition of the Buchanan gravels was certainly long if counted in the ordinary units of time; but its duration is only imperfectly and indefinitely indicated,—by no means measured,—by the extent of the erosion, weathering, and leaching which took place during its progress in the exposed surface of the Kansan till. This interval was marked by fluctuations of climate due to the approach and withdrawal of the glaciers of the Illinoian age. In time, however, during what has been called the Iowan division of the glacial epoch, a depression of temperature brought about a renewal of glacial conditions, and Dubuque county was again invaded by glacier ice. During the Iowan stage glaciers were not developed in such force as during the Kansan; the terminal margin of the ice sheet, even when the glacial conditions of this stage had reached their maximum, lay for the most part west of the Dubuque county line; but a few narrow tongues of ice favored by certain low-lying tracts of land, flowed out from the margin, invaded the county, and occupied the small, peculiarly shaped areas which have been mapped as Iowan drift. The amount of Iowan till deposited in these areas is very small, but the areas are, nevertheless, readily distinguished by certain unmistakable characteristics. In the first place the surface is comparatively level, its inequalities are constructional, it has not been cut and carved and modeled in any way by erosion. In the second place the surface is not covered with loess; the rich black loamy soil which at once distinguishes it has been developed upon bowlder clay. Then again the surface is liberally sprinkled with large granite bowlders which, taken as a whole in all their aspects and peculiarities, are not duplicated by anything found in connection with the Kansan till. The surface of the Iowan drift has not been leached or oxidized, nor have the Iowan bowlders suffered decay, to even approximately the same extent as may be noted in connection with the Kansan. The Kansan is relatively old; all the characteristics of the Iowan indicate newness. Where the body of Iowan till is fully developed, as in Buchanan, Bremer and Black Hawk counties, it is fundamentally a yellow clay rich in lime carbonate. It usually carries only a small number of pebbles and cobblestones, and all of these, practically, are fragments of northern crystalline rocks. Local limestones and cherts are rare in the Iowan drift. In Dubuque county the sheet of Iowan till, as has been said, is small in amount; so thin in fact that it has been quite completely modified by the growth of plants and converted into a dark carbonaceous soil.

The Iowan drift in Dubuque county is distributed in three relatively small areas, which, for convenience, may be designated, respectively, the Farley lobe, the Worthington-Bernard lobe, and the southwestern area. The southwestern area is part of a lobe in the northern part of Jones county, the outlines of which have not yet been traced. The space it occupies in our present territory is less than four square miles. The Farley lobe enters the county at Dyersville, trends southwest past Farley, and terminates in a number of lobules which interdigitate with loess-covered Kansan ridges south of Epworth. The southern lobule is continued into section 35 of Taylor township. The margin of the Farley

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lobe is very sinuous and irregular along its northeastern edge, owing, apparently, to the number of pre-Iowan hills, among which the motile ice became entangled, and which it was unable to overflow. Worthington is located near the beginning of the middle lobe of the Iowan ice which invaded Dubuque county. The width of the lobe was at first about three miles. Its trend across Dodge, the northeastern part of Cascade, and on to near Fillmore, in White Water township, is about parallel to that of the Farley lobe. Northwest of Fillmore the ice seems to have been contracted to the limits of a narrow gorge through which it passed; and then, widening out, it flowed more nearly eastward past the site of Bernard into section 35 of Prairie Creek township. Evidences of the unusual motility and anomalous behavior of the marginal portions of the Iowan ice have been previously noted.*

Loess.—The fine, homogeneous, yellow silt, known as loess, covers practically the whole area of the county, except the small portions occupied by the Iowan drift, the Wisconsin terraces, and the more recent alluvium. The loess is superficial, therefore, over most of the Kansan area and the driftless portion of Dubuque county, and so has a wider distribution than any of the other Pleistocene formations. It is fresh, unweathered, and unleached, as compared with the upper surface of the Kansan drift and the Buchanan gravels, upon which it rests in the region west and southwest of the thickened Kansan border. It differs markedly in color and composition from the dark, tenacious clays and other residual products which it overlies throughout the driftless area. The age of the loess seems to coincide with that of the Iowan drift. There are reasons for believing that it was deposited while the Iowan ice was at its maximum development. It was not laid down, therefore, on Iowan areas, for at the time of its deposition these areas were still occupied by Iowan glaciers. By some agent or agents fine dust-like material, derived from the Iowan till, was distributed outward from the Iowan margin and spread as a thin veneer over the uneven, eroded surface of the extra-marginal territory. That wind was one of the agents concerned in the transportation and distribution of the loess is rendered highly probable by the researches of

*Report on the Geology of Delaware county; Iowa Geol. Surv., Vol. VIII, p. 172. *The Iowan Drift*, by Samuel Calvin; Bull. Geol. Soc. of America, Vol. X, p. 119.

Shimek, Udden, Wilder† and many others who have thoroughly investigated the problems involved. While the peculiar deposit in question is spoken of as a veneer covering the pre-loessial surface, it is true that it varies greatly in thickness in different localities, ranging in this respect from a few inches to more than thirty feet. It lies everywhere unconformably upon a surface which had previously been carved and moulded by erosion. It contains many fossils, among which the most common are shells of land snails belonging to species that may still be found living upon the surface. Near the Iowan margin the basal portions of the loess usually contain a considerable amount of sand. It would seem as if the first outwash from the edge of the Iowan ice consisted of a fine sand which was sometimes obscurely, and sometimes distinctly stratified; and that later the sand was overlaid with the finer dust or silt which makes up the typical loess. Except along the larger streams the sandy phase of the loess does not extend more than two or three miles from the border of the Iowan area. The main body of the loess is frequently obscurely stratified, the stratification in some cases being indicated only by alternating moister and drier bands.

WISCONSIN TERRACES.

After the deposition of the Iowan drift and the contemporaneous loess, northeastern Iowa, and the regions northward to an extent at present unknown, were freed from their mantle of ice and experienced the effects of the short Peorian interglacial interval. The Peorian interval was followed by the ice invasion of the Wisconsin stage, but the glaciers of this stage did not extend as far as Dubuque county. The main river valley, however, was occupied with Wisconsin ice in Wisconsin and Minnesota, and tributaries which enter the Mississippi not far above Dubuque had the upper parts of their drainage basins choked with advancing marginal portions of the great Wisconsin ice sheet. During the advance,

†See Wilder's report on Lyon and Sioux counties, this volume, pp. 121 and 145.

the culmination, and the final melting of this ice the Mississippi and its upper tributaries were flooded, and the torrential floods were loaded with detritus. As a result outwash sands and gravels of Wisconsin age are prominent along the Mississippi throughout Dubuque county. These deposits fill up the old valley to a depth of some hundreds of feet, and they form well defined terraces which show wherever there is a lateral enlargement of the valley. The widening of the valley afforded an opportunity for the existence of slack water in which deposition was possible. Dubuque proper is in part built upon a Wisconsin terrace, and the manufacturing establishments near the river draw their water supply from the sands and gravels of which it is composed. Easily studied examples of these terraces are found in many places. One of the best and most accessible is the sandy ridge between Rhomberg avenue and the river. This has been cut in many places in the process of street grading, and sections twenty feet or more in height, showing perfectly the definite banding and stratification of the materials, have thus been exposed. The gravel pits near Peru also show the terrace material to advantage; and deposits of the same age are well exposed near the point where the Illinois Central railroad turns away from the Mississippi into the abandoned portion of the valley of Catfish creek. The surface exposures of these deposits, both at Dubuque and over the Peru bottoms, yield gravels for road making, and sand for building purposes.

The Wisconsin terraces contain a large amount of foreign material, but along the tributary streams, away from the immediate vicinity of the Mississippi, foreign material is absent. In Wisconsin time the drainage seems to have been essentially as it is now. The flooding and filling of the main river channel caused back water in the tributaries, and the lower courses of these tributaries were accordingly filled with local material to the same height that the main channel was filled with foreign gravel and sand. Where an important tributary appeared, large quantities of detritus were dropped by both streams; and, for example, at the mouth of the Little Maquoketa, the terrace rises sixty feet above the bottom land. In this locality the Wisconsin material forms a barrier which the tributary stream avoids by running north along the bluff to the Mississippi.

ALLUVIUM.

The term alluvium may be used for any material deposited on river flood plains. The terraces noted above are definitely referred to the Wisconsin age of the glacial epoch; but there are fluviatile deposits along the streams in the interior of the county, the age of which cannot be determined. Some may be older, some are certainly newer than the Wisconsin. There are true alluvial deposits along the North Maquoketa in Cascade township, and similar deposits occur along the Little Maquoketa and its branches wherever the valleys have been cut to grade and have been widened so as to produce a definite flood plain. Even along the minor drainage courses the stream valleys occasionally show small patches of alluvium. These are due to inequalities in the hardness of the rock, to the coming in of side streams, to changes of course, and similar factors. Upon the accompanying map these minor areas have not been discriminated; nor have the Wisconsin terraces proper been set off from the synchronous terraces of local material, or from the true alluvium.

SUMMARY OF PLEISTOCENE HISTORY.

Since the beginning of the Pleistocene it is probable that Dubuque county was three times invaded by glaciers, (1) during the pre-Kansan age, (2) during the Kansan, and (3) during the Iowan. During two of the recognized ages of the glacial epoch, the Illinoian and the Wisconsin, the county was not reached by the respective sheets of ice belonging to the intervals of glaciation. In both cases the glaciers did not come within many miles of the borders of the county, but their influence on the climate must have been felt, and the Wisconsin terraces are permanent effects of the latest approach of glacial conditions. Five times the region suffered the rigors of an Arctic climate, and five times climatic conditions were ameliorated; the amelioration which followed the Wisconsin stage introduced the conditions now characterizing this part of the continent. The interglacial interval, the Aftonian, which preceded the invasion of the Kansan glaciers, was marked by the growth of forests. In these Aftonian forests the spruce and the larch were among the commonest of the trees, but according to the well records of McGee it is probable that trees with broad, deciduous leaves, such as the elm, were also present.

There is reason to believe that at the time of melting of the Kansan ice the surface of Iowa was at least as high as it is at present. At all events the drainage was energetic; and vigorous currents transported for long distances the coarse materials which were finally deposited to form the Buchanan gravels. The ice may have melted rapidly and so have given volume to the floods which swept out from the edge of the retreating ice over the recently bared surface, and in this way part of the energy of the drainage streams may be accounted for; but the evidence indicates a time of moderate elevation of the land, unimpeded drainage, and currents loaded with detritus. There are rounded rock fragments in the Buchanan gravels ranging from three or four, to eight or ten inches in diameter.

The melting of the Iowan ice evidently took place without giving rise to currents strong enough to carry particles larger than fine sand; and even this was not transported more than a very few miles except along the larger drainage courses. The materials carried outward from the margin of the Iowan ice make up the present fine-grained loess, and it is probable that wind may have been as efficient an agent as water in their distribution. It is probable that, at this time, the land stood much lower than now, and that the drainage was so choked and sluggish that nothing but the finest silt was carried any great distance from the edge of the melting ice. The feeble character of the drainage may have been due in part to the fact that the ice was thin and that it melted so slowly as not to give rise to vigorous floods. Whatever the cause or combination of causes, the agents of transportation which operated in connection with the melting of the Iowan ice, carried only the very finest of materials.

The events which closed the Wisconsin glacial stage are in strong contrast with those which closed the Iowan. The culmination and departure of the Wisconsin glaciers were attended with floods greater and more energetic, even, than those of the Kansan—a fact very clearly attested by the enormous quantities of sand and gravel, fifty to a hundred feet in thickness, heaped up along all the drainage courses leading outward from the margin of the Wisconsin drift. These materials, becoming progressively finer, are strewn along the stream valleys for scores or hundreds of miles. Their volume and character are well illustrated by the Wisconsin terraces of Dubuque county, already described.

Calcareous Tufa.—Wherever springs issue, or have issued from the Galena-Trenton limestone, a certain amount of calcareous material is found deposited from solution. These chemical deposits are usually porous; but occasionally the pores are filled solid, and the product takes on the form of travertine. The presence of algæ, or of partially submerged mosses and liverworts, seems to facilitate the process of deposition by reason of the fact that the green plants quickly absorb the carbon dioxide, the presence of which gives to spring waters, in their underground courses, the power of taking up and holding carbonate of lime in solution. The lime is very frequently deposited as a thin crust on the stems of the plants, and some of the forms which it thus eventually assumes, are known as "petrified moss." Along the river bluffs from Eagle Point to Waupeton, calcareous tufa is a common characteristic, occurring in places in great masses several feet in thickness, and everywhere cementing the shingle and scree and loose fragments of all kinds strewn over the face of the bluff, into a sort of tufaceous breccia. The process is still in operation. It has doubtless been active ever since the river channel was cut to any considerable depth, ever since spring water, in any volume and at any level, issued from the seams and fissures of the rocks and moistened the face of the bluffs. The deposit is probably all Pleistocene; some of it may be preglacial in age; some of it was formed but yesterday.

DEFORMATIONS.

The indurated rocks of Dubuque county have suffered deformation on a small scale. They have been subjected to enough of strain and lateral crushing to throw them into a series of low anticlinal and synclinal folds, and the force was applied in such wise as to give the folds a general east-west trend. The folds may be studied to best advantage along the river bluffs, and one of the best localities occurs a mile or two above, and a mile or two below, Specht Ferry. Some of the anticlines are sufficiently striking to receive attention from persons going up or down the river on passing boats. The most pronounced fold is that which constitutes the Eagle Point anticline noted in connection with the description of the Galena limestone. The strains which resulted in the formation of folds gave rise to the joints and fissures and evidences of shearing which will be more fully discussed in connection with the occurrence of the ores of lead and zinc.

UNCONFORMITIES.

There are no evident unconformities between any consecutive formations of the indurated rocks in Dubuque county. The band of coarse materials above the top of the Galena limestone, and its probable significance, have been noted in discussing the Maquoketa shales. The Pleistocene deposits, however, are unconformable with the indurated rocks and amongst themselves. The pre-Kansan, if present, and the

Kansan certainly, if the older drift is absent, was laid down upon an eroded surface; the Iowan drift and the loess are unconformable on the Kansan; the loess even overlaps the indurated rocks of the driftless area; and the Wisconsin terraces are confined to old erosion valleys.

ECONOMIC GEOLOGY OF DUBUQUE COUNTY.

SOILS.

Dubuque county has, for an Iowa county, more than the usual variety of soils. The original soils were composed wholly of residual products, and in some parts of the driftless area the soils are yet largely residual. During the Iowan division of the Pleistocene the whole surface, outside the margin of the Iowan ice, received a deposit of loess of greater or less thickness, and loess soils are now by far the most common within the area we are considering. Loess is the most valuable of the soil materials in the vicinity of Dubuque and throughout the driftless area. Loess is a porous material permitting the free distribution of gases and moisture; it is quite calcareous in composition, and is, therefore, well adapted to the production of grasses and all kinds of grains. All varieties of fruits flourish well in loess soils. Within the driftless area the loess overlies residual products, or geest. The geest usually contains more or less of tenacious clay which tends to hold the moisture near the surface; and this moisture, in times of drought, is brought, by capillary action in the porous loess, within reach of the roots of plants. In the loess-Kansan area the soil is composed of loess overlying Kansan drift. On steep hillsides the loess washes badly, and the soils are consequently thin and poor. But in the regions of gently undulating loess-Kansan there is developed a brown, friable loam of qualities unexcelled for agricultural purposes. These regions are large, as has been noted in the section on topography, the surface is thoroughly drained, the conditions for successful farming are as favorable as could well be imagined. The soil of the Iowan areas is, in general, a dark, rich loam upon which grasses grow luxuriantly, and corn, the staple crop of Iowa, does remarkably well. If any disadvantages are to be mentioned at all in connection with Iowan soils, they are to be found in the imperfect drainage of some localities, and in the further fact that, in places, the surface is encumbered with large granite bowlders. There are also some Iowan areas which are quite sandy, as, for example, sections 15, 16, 21, 22, and 25 of White Water township. But the level character of the Iowan surface is in striking contrast with the steep hills of the driftless areas, and with even the minor erosional irregularities of the loess-Kansan; and this gives it a great advantage in the facility with which improved agricultural machinery may be used.

In the forestry notes on the county, by Professor Macbride, there are many valuable and timely suggestions respecting the soils. In particular the waste of soils on the steep slopes of the driftless area and the manner in which such surfaces can be utilized to greatest profit are discussed in a manner deserving careful consideration.

LEAD AND ZINC.

HISTORICAL SKETCH.

The Dubuque mines have for the geologist and mining engineer a rare historical interest. They were the first of the upper Mississippi mines to be opened and among the first in America to be developed. In earlier years they were the most important source of lead in the world aside from the mines of northern England and of Spain. At one time they were considered far more valuable than the lower Mississippi or Missouri mines. Leadville and the other famous lead-silver mines of the west were then unknown. Iowa and the surrounding region was then "the west" and the Rocky mountains and the Cordilleras were not within the limits of practical exploration. As late as 1852 the Upper Valley mines produced 13,000 tons of lead; 10 per cent of the world's production of that year and 87 per cent of that of our own country. That was a century and a half after the mines were first seen by white men and nearly half as long since the first attempt had been made to work them.

It was Le Sueur who in his voyage up the Mississippi in 1700, or possibly in an earlier voyage, first noted the presence of lead both in the upper and lower Mississippi valley. The Indians had doubtless known of the presence of this mineral before this, but it may be considered certain that they knew nothing of smelting until taught later by white men. Le Sueur's voyage did not result in any attempt to work the upper mines, though the presence of mineral in the vicinity was not lost sight of and was duly noted by Guettard* and the mines were located by Bauche on one of the earliest of geological, or rather as they were then called, mineralogical maps. The first attempt to work the mines of the Mississippi valley was made in Missouri. In 1820 the "Company of the West" organized in France by John Law, sent out Renault and La Motte, or La Mothe according to one spelling, and commenced mining in the Ozarks. The famous Mine La Motte was first opened at this time and has been worked more or less constantly ever since.

It was more than half a century later that the upper mines were first worked. According to Schoolcraft,* to whom we are indebted for the first published account of the Dubuque mines, the discovery of lead was made by the Indians themselves, as he states in the following paragraph:

"In 1780 a discovery of lead ore was made upon their lands by the wife of Peosta, a warrior of the Kettle Chief's village, and extensive mines have since been discovered. These were granted by the Indians to Julien Dubuque at a council held at Prairie du Chien in 1788, by virtue of which he settled upon the lands, erected buildings and furnaces, and continued to work the mines until the year 1810. In the meantime (1796)

* Histoire de l' Academie Royale, des Sciences, 1752, pp. 189-220.

*Schoolcraft, H. R., Narrative Journal of Travels, etc., Albany, 1821, p. 348.

he received a confirmation of the Indian grant from the Baron de Carondelet, governor of Louisiana, in which they were designated the 'Mines of Spain.'"

Under Dubuque's regime several mines were opened up, though it seems that no shafts were sunk. The ore was obtained by means of the hoe, shovel, crowbar and pick from carelessly protected drifts. Good roads were, however, built to the furnaces, one of which was erected near the mouth of Catfish creek, where Dubuque had his house in Kettle Chief's village. It is stated that up to recent years the sites of two of Dubuque's furnaces were well known—one on Eagle Point avenue, near Heebs' Brewery, and the other between Main street and the river. Hon. M. M. Ham has given us† a graphic account of Dubuque and of his life among the Indians.

A visit to Dubuque was one of the objects of Lieutenant, later General, Pike's expedition up the Mississippi in 1805. He found M. Dubuque "polite but evasive," and did not visit the mines, although there is an interesting statement signed by Dubuque and Pike in 1805, in which it is declared that 20,000 to 40,000 pounds of lead were made per annum, that being a yield of 75 per cent. It is also stated that copper had at that time been noticed, though no attempt had been made to reduce it.

After Dubuque's death the Indians burned his house and fences and destroyed all traces of civilized life. They continued, however, to work the mines intermittently, selling the ore to certain Indian traders who were located on islands in the river.

Dubuque died in debt, but before his death he assigned his claims to his creditors, and out of this fact grew a controversy as to the possession of the property. The claims, however, were never allowed, the government taking the ground that both the Indians and the Spanish governor, Carondelet, gave to Dubuque simply permission to work the mines, and that this permission was personal to him. There was in the

†Annals of Iowa, Vol. II, Third Ser., pp. 329-344, 1893.

Spanish grant no provision for a survey of the land, nor were other forms customary in making a grant followed. Dubuque's original request for "peaceable possession of the mines" was merely indorsed, "granted as is asked (*concedido como sa solicita*)."

It was twenty years after Dubuque's death in 1810, that white men again attempted to work the mines. Certain miners from Galena, attracted by the reputed richness of the Dubuque mines, and acting under the authority of the Dubuque heirs, crossed the river and began work. It is said that the Langworthy crevice on Eagle Point avenue was opened at this time. The government held, however, that the country was not yet open to settlement, and troops from Prairie du Chien drove out the miners and burned their cabins. The development of the mines across the river had in the meantime been in progress, but for some years yet the Iowa mines were worked by the Indians. Schoolcraft in 1820* made a canoe voyage from Prairie du Chien to the present site of the city, at that time known as the Kettle Chief's Village. The main workings at that time seem to have been west of the river, although Schoolcraft enumerates, in addition to the Dubuque mines the "Sissinaway mines" and the "Mine au Fevre;" the former the prototype of the Wisconsin mines and the latter the earliest workings at Galena. What are known as the Durango diggings, then passed under the name of the Mine of Maquanquitons. Schoolcraft's description, the first which we have of the mines at Dubuque proper, is as follows:

The district of country generally called Dubuque's lead mines, embraces an area of about twenty-one square leagues. Commencing at the mouth of the Little Maquanquitons river, sixty miles below Prairie du Chien, and extending along the west bank of the Mississippi seven leagues, commencing immediately at the Fox village of the Kettle chief, and extending westward. This is the seat of the mining operations formerly carried on by Dubuque, and of what are called the Indian diggings. The ore found is the common sulphuret of lead, with a broad foliated structure and high metallic lustre. It occurs massive, and disseminated, in a reddish loam, resting upon limestone rock, and sometimes is seen in small veins pervading the rock, but it has been chiefly explored in alluvial soil. It

*Schoolcraft, H. R., Narrative Journal of Travels, etc., Albany, 1821.

generally occurs in beds or veins which have no great width, and run in a certain direction 300 or 400 yards,—then cease, or are traced into some crevice in the rock, having the appearance of a regular vein. At this stage of the pursuit most of the diggings have been abandoned and frequently with small veins of ore in view. No matrix is found with the ore which is dug out of the alluvial soil, but it is enveloped by the naked earth, and the lumps of ore are incrusted by an ocherous earth. Occasionally, however, some pieces of calcareous spar are thrown out of the earth in digging after lead, and I picked up a solitary specimen of the transparent sulphate of barytes, but these substances appear to be very rare. There is none of the radiated quartz, or white, opake heavy spar, which is so common at the Missouri mines. The calcareous rock upon which this alluvial formation, containing lead ore, rests, appears to be referable to the transition class. I have not ascertained its particular extent about the mines. The same formation is seen, overlaid by a distinct stratum of compact limestone, containing numerous petrifications, at several places between the mines and Prairie du Chien. The lead ore at these mines is now exclusively dug by the Fox Indians, and, as is usual among savage tribes, the chief labor devolves upon the women. The old and superannuated men also partake in these labors, but the warriors and young men, hold themselves above it. They employ the hoe, shovel and pick-axe, and crow-bar, in taking up the ore. These things are supplied by the traders, but no shafts are sunk, not even of the simplest kind, and the windlass and bucket are unknown among them. They run drifts into the hills so far as they can conveniently go without the use of gunpowder, and if a trench caves in it is abandoned. They always dig down at such an angle that they can walk in and out of the pits, and I descended into one of these which had probably been carried down for forty feet. All this is the work of the Indian women and old men, who discovered a degree of perseverance and industry, which is deserving of commendation. When a quantity of ore has been gotten out, it is carried in baskets by the women to the banks of the Mississippi, and then ferried over in canoes to the island, where it is purchased by the traders at the rate of $2 for 120 pounds, payable in goods sold. At the profits at which these goods are usually sold it may be presumed to cost the traders from 75 cents to $1, cash value, per 100 weight. The traders smelt the ore upon the island, in furnaces of the same construction used at the lead mines of Missouri, and observe that it yields the same per centum of metallic lead. Formerly the Indians were in the habit of smelting their ore themselves, upon log heaps, by which a great portion was converted into what are called lead-ashes, and thus lost. Now the traders induce them to search about the sites of the ancient fires, and carefully collect the lead ashes, for which they receive $1 per bushel delivered at the island, payable in merchandise.

As early as 1821 something was done in Wisconsin and Illinois by the white miners, but it was not until 1827 that mining really became active. From that time the development of the Illinois and Wisconsin mines was uninterrupted except by the Black Hawk war. The history of these years in Iowa is summarized by Dr. Leonard as follows:*

*Iowa Geol. Survey, Vol. VI, p. 16.

At the close of the Black Hawk war, the large tract known as the Black Hawk purchase, including one-third of the present area of Iowa, was ceded to the United States by the Sacs and Foxes. After the completion of the treaty negotiations, the miners again crossed over into the coveted region, where they built cabins and commenced to take out much ore. But a second time they were forced to leave because the treaty had not been ratified. In June, 1833, the treaty went into effect and the way was at length clear for settlers to take possession of the land. During the next few years large numbers flocked in, prospecting was actively carried on and many mines were soon in operation.

A superintendent of mines was appointed by the government and a system of permits to miners and smelters was adopted. For some years the smelters were required to pay 6 per cent of all the lead produced. This tax was the cause of much dissatisfaction and was abolished at the end of ten years.

The first "legislation" in Iowa dates from 1830. In June of that year a number of miners met on the banks of the Mississippi and enacted regulations to govern them in their relations to each other. One of the articles was that "every man shall hold 200 yards square of ground by working said ground one day in six." Much other interesting early history clusters around these mines but it is foreign to our purpose to go into that phase of the subject here.

Aside from the historical interest the mines are worthy of study from the fact that it was here that some of the elemental ideas as to ore deposits were worked out. It was in the study of the Dubuque mines that "gash" veins were first discriminated and in the latest text-books, both of this and foreign countries, they are still cited as the type. Whitney, in his writings on the region, made what is in many particulars the first complete application of the theory of lateral segregation to the origin of ore deposits. Previously a deep-seated source had been almost universally assumed as *a priori* the more probable. Since the mines were first worked our ideas of ore deposits and many of our conceptions of geology in general have radically changed, and it is well to keep this in mind in reading the earlier accounts of the region.

In the first description of the mines published, Schoolcraft, who was a careful and painstaking observer, refers the country rock of the region somewhat vaguely to the "transition" period. This indefiniteness of reference arose less from lack of observation than of precision in ideas.

It is a little difficult at times to remember how recently the science of geology has come into being, and in re-reading the descriptions of the mines left us by various investigators up to the middle of the present century, it is important to remember how much our ideas of geology and of ore deposits have changed. It was only in 1807 that the Geological Society of London was organized, and a serious attempt was made to substitute observation for theory in geology. It was as late as 1818 that the first number of the *American Journal of Science* was published in New York, and in the first interesting number of that journal* it is said that "geological researches are now prosecuted by actually examining the structure and arrangement of districts," and the accent was evidently intended to be placed upon the word "now." It is important to keep in mind the mental atmosphere in which the first explorers lived in order not to give undue value to their theoretic beliefs as to the origin of the ores.

As has been seen, a visit to Dubuque was one of the objects of Pike's expedition up the Mississippi, but the first strictly geological exploration was not undertaken until 1836, when G. W. Featherstonhaugh, having visited the year before, the mines of Missouri, was employed by the general government to make a reconnoissance in the northwest. In the course of the work he visited the upper mines, but in his report there is little of value.†

When the mines were first developed the government adopted a plan of leasing them, but owing to difficulties in securing the payment of these royalties it eventually became necessary to sell the lands. Preliminary to this a survey was ordered in 1839, and placed in charge of that pioneer western geologist, D. D. Owen. This survey was in many particulars unique. The field work was begun in September and, with the aid of a large number of assistants, was finished before winter; a report, accompanied by maps, sections, figures, descriptions and fossils, being submitted to the Land Office on the second of the following April. This report was

*Page 7.

†Report of a Geological Reconnoissance made in 1835 from the seat of government, by way of Green Bay and the Wisconsin territory, to the Coteau de Prairie, p. 158, Washington, 1836.

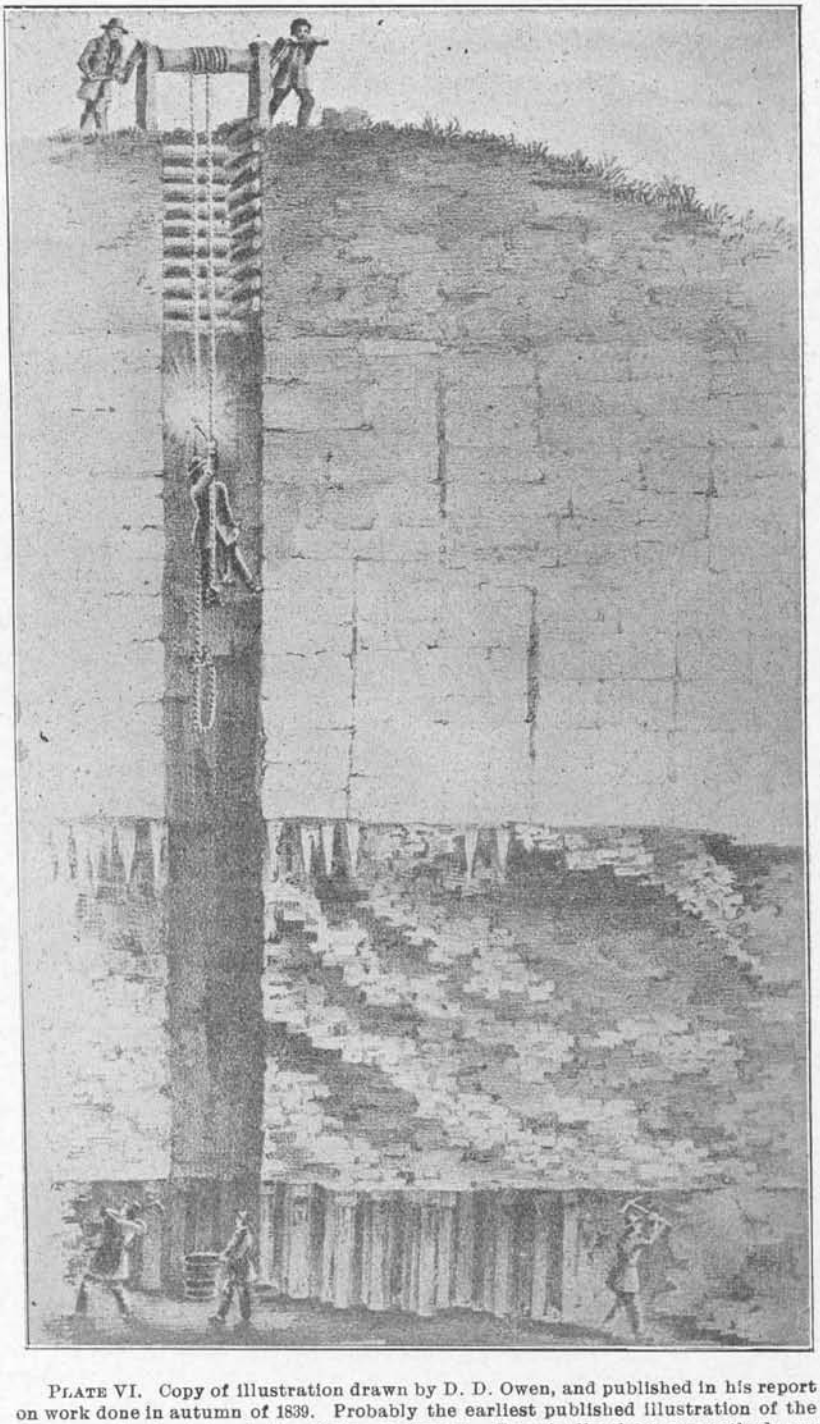

PLATE VI. Copy of illustration drawn by D. D. Owen, and published in his report on work done in autumn of 1839. Probably the earliest published illustration of the process of lead mining in the Dubuque district. Practically the same methods are now in use.

printed without illustrations* in June of the same year, and a revised edition, including the omitted plates, was printed in 1844.† In this survey a large area, including the whole of the mining section, was traversed township by township, and the character of the rocks was noted. An estimate of its geologic value is given elsewhere in this paper. In 1847 Owen executed for the Treasury Department another survey of the Chippewa Land District, and in his report on that region‡ gives certain additional details regarding the lead and zinc region.

In the course of a still later survey he visited the region again and in his well known quarto report there is a brief discussion of the geological formations present.§ Owen was accordingly the first geologist of note who studied the region in detail, and his conclusions, based as they were upon a long and intimate acquaintance with it, are worthy of the utmost respect. It is curious to note, however, that he entirely overlooked the Maquoketa shale and confused the Galena and Niagara; and it can be readily believed that in this, as well as in his opinions respecting the deep seated origin of the ore deposits, he was misled by the ideas then current and accepted.

In 1854, J. D. Whitney, than whom no one has done more correctly to interpret the phenomena of the region, published his Metallic Wealth of the United States.‖ Having made certain investigations in the region in the course of his private professional work, he gave a very accurate though brief account of the mines. His ideas were later elaborated in the course of his work for the three states, Iowa, Wisconsin and Illinois, for which he successively studied the field. In his reports on these states he covers the whole ground excellently, and it is no disparagement to others to say that

*House Rep. Exc. Doc., 26th Cong., 1st Sess., No. 239, 161 pp., Washington, 1840.
†Rept. Geol. Exp. Iowa, Wis., Ill., made in autumn 1839, Washington, 1844.
‡30th Cong., 1st Sess., Sen. Ex. Doc., No. 57, 134 pp., Washington, 1848.
§Rept. Geol. Surv., Wis., Iowa and Minn., 638 pp., Philadelphia, 1852.
‖Philadelphia, Lippincott, Grambo & Co., 1854.

together his reports form the best and most complete account of the field ever published.*

Professor Whitney's report is extensively quoted elsewhere in this paper. He visited the region in the years of the maximum importance of the lead mines and his observations are accordingly particularly valuable. It was, however, after his work was finished that zinc became of value in the region. Industrial conditions have also largely changed so that there is now much of interest to be added to his report.

Aside from Whitney and Owen, the best known of the earlier investigators in this region was Percival, who in 1854 and 1855 made a study of the lead region for the state of Wisconsin. Accuracy of observation is everywhere characteristic of Percival's work, but his conclusions as to the origin of the ores and the best methods of working them seem to have been unfortunate.† Like Owen he followed the current theory of the period. Blake has recently shown, however, that Percival was the first to recognize correctly the presence and importance of faults in the region.

The later Wisconsin survey renewed the study of the region and in the elaborate papers of Strong‡ and Chamberlin§ we have much the most detailed study of the region extant, with, in the latter case, a notable addition to the discussion of the theoretic considerations involved.

The fall in the price of silver and the consequent closing of many of the lead-silver mines of the west led renewed attention to be directed to the soft lead deposits of the Mississippi valley. The most notable contribution to the literature of the subject resulting was the report on the lead and zinc deposits of Missouri by Winslow and Robertson‖ published in 1894. While nominally devoted to the Missouri field

*Geol. Iowa (Hall), Vol. I, pp. 286-295, 422-471, Albany, 1858. Geol. Wis. (Hall), Vol. I, pp. 73-424, 1862. Geol. Ill., Vol. I, pp. 153-207, Springfield, 1866.

†Percival, J. G., Ann. Rept. Geol. Surv. Wis., 101 pp., 1855. (Second) Ann. Rept. Geol. Surv., Wis., 111 pp., 1856.

‡Geol. Wis., Vol. II, pp. 643-752, 1877.

§Geol. Wis., Vol. IV, pp. 365-571, 1882.

‖ Lead and Zinc Deposits by Arthur Winslow assisted by James D. Robertson. Missouri Geol. Surv., Vols. VI and VII. Jefferson City, 1894.

the report covers practically the whole subject, and there are quite full notes on the upper mines though nothing original is attempted in the latter field. The meeting of the International Engineering Congress at Chicago in 1893, and the reading there of Posepney's famous paper on the origin of ore deposits, led, directly and indirectly, to the publication of a number of papers in which the phenomena of the region are discussed. Among the more important, with others of the same period, are those of Posepney*, Jenney†, Blake‡, Winslow,§ Robertson‖, Chamberlin¶, and Roethe**.

Since the organization of the present survey considerable attention has been devoted to the study of the lead and zinc region. Dr. A. G. Leonard prepared a preliminary report upon the lead and zinc mines of the state which was published in 1896.†† He also published several short papers on the same subject.‡‡ Calvin,§§ has made a study of the mines in the lower Magnesian or Oneota dolomite, and since the present work began brief notes have been published in Mines and Minerals‖‖ and the Mineral Industry.¶¶

GEOLOGY.

The general geology of the region has already been sufficiently described in an earlier portion of this report. It remains but to emphasize certain points which are believed to have especial significance in connection with the origin and distribution of the ore bodies.

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*Posepney: Trans. Amer. Inst. Min. Eng., Vol. XXIII, pp. 197-369; XXIV, p. 207.

†Jenney; Ibid, Vol. XXII, pp. 171-225.

‡Blake; Ibid, Vol. XXII, pp. 558-568, 569-574, 621-646, XXIII, 587. Bul. Geol. Soc. Amer., Vol. V, pp. 25-32. Trans. Wisconsin Acad. Arts. Sci. Let. Dec., 1892; Amer. Geologist, Vol. XII, pp. 237-248.

§Winslow; Trans. Amer. Inst. Ming. Eng., XXIII, pp. 528-529. Jour. Geol. Vol. I, pp. 612-619.

‖Robertson; Amer. Geologist, Vol. XV, pp. 235-248.

¶Chamberlin; Bul. Geol. Soc. Amer., Vol. V, p. 32.

**Roethe: Eng. Min. Jour. Vol. LX, pp. 88-89.

††Lead and Zinc Deposits of Iowa, by A. G. Leonard, Iowa Geol. Surv., Vol. VI, pp. 9-66.

‡‡Eng. Min. Jour., Vol. 61, p. 614; Amer. Geologist, Vol. XVI, pp. 288-294: Proc. Iowa Acad. Sci., Vol. I, pt. IV, pp. 48-52, Ibid, Vol. II, pp. 36-38, Ibid. Vol. III, pp. 64-66.

§§Iowa Geol. Surv., Vol. IV, pp. 103-107.

‖‖Bain: Mines and Minerals, Vol. XX, No. 1, pp. 10-12.

¶¶The Mineral Industry, Vol. VIII, pp. 636-638, New York, 1900.

In general the rocks of the region consist of a series of sedimentaries including limestones, dolomites, shales and sandstones. The rocks exposed within the limits of the county form only a portion of a larger series, in part now buried and so not open to observation, and in part removed, so far as this particular area is concerned, through the process of erosion. The rocks which underlie the oldest rocks exposed in Dubuque county may be studied in Allamakee and Clayton counties, Iowa, and in adjacent portions of Wisconsin. They consist essentially of alternating sandstones and dolomites belonging to the Cambrian and Lower Ordovician formations. The most important of these buried dolomites is the Oneota, or as it was formerly called the Lower Magnesian limestone. These underlying sediments rest upon a still older series of rocks, probably largely metamorphic in character, and only reached in Iowa in the deepest drill holes. These metamorphic rocks seem to have formed, in early Cambrian time, a land mass around the southwest flank of which the lead-bearing rocks, with the accompanying barren beds, were deposited.

Saint Peter Sandstone.—The lowest rock exposed in the county is the Saint Peter sandstone, a porous, friable, water-bearing rock which never shows any signs of mineralization. It is exposed along the base of the bluffs from the mouth of the Little Maquoketa, north, dipping to the south. There can be no doubt that it underlies the whole of Dubuque county, in fact it has been penetrated in the deep wells of northeastern Iowa so frequently as to preclude any possible doubt of its continuity and uniform character throughout the region.* It is significant from the present point of view that the Saint Peter, though cut by innumerable streams and exposed over many square miles of Iowa and adjacent states, has never at any point been shown to be mineral-bearing. The only possible exception to this statement is the case of the Crow Branch diggings in Wisconsin, where mineral was

*Norton: Artesian Wells of Iowa, Iowa Geol. Surv., Vol. VI, 181, 202 *et seq.*

found running down to the sand rock, and has been reported to have run into it.* In this case, however, it was apparently a merely local instance of an upper ore body following a crack down into the sandstone. It was essentially similar to the occurrence near Lansing of several thousand pounds of mineral in the top of the St. Croix sandstone at the base of an important crevice through the Oneota. The Saint Peter is a barren formation, and, furthermore, is not characterized by either crevices or caves, though the latter do occur.†

In the second place the Saint Peter is an important source of artesian water throughout Iowa. A large number of wells in the eastern part of the state derive their supply in whole or in part from this formation. This water is under pressure and seeks to rise through any opening driven down to it. It is usually charged with certain salts which are characteristic, and which enable the water from this horizon to be readily recognized. An analysis of characteristic water from the Saint Peter is given below:

ANALYSIS OF WATER FROM MONONA WELL.*

*Norton: Iowa Geol. Surv., Vol. VI, p. 188.

	GRAINS IN U. S. WINE GALLONS.
Calcium carbonate	7.14
Magnesium carbonate	8.95
Calcium sulphate	10.41
Alkaline sulphates	.63
Alkaline chlorides	1 87
Silica, alumnia, and oxide of iron	.10
Total	29.10

A majority of the artesian wells of the region draw their supply not only from this but from lower sandstones belonging to the Cambrian. The water derived from these wells is, however, all strongly mineralized and very characteristic. The fact, however, that the analyses from particular horizons are characteristic and that the pressure is distinct from each horizon argues against any general connection between these different

*Whitney: Geol. Wisconsin, p. 363.
†Calvin: American Geologist, Vol. XVII, pp. 195-203.

water-bearing horizons; that is, there is no general set of open crevices running down through them or from one to the other.

Galena-Trenton.—Before discussing in detail the various members of this group there are certain questions relating to the series as a whole which may be noted. As has already been shown the Galena-Trenton is made up of dolomite, dolomitic limestone and non-magnesian limestone, with a very subordinate amount of shale or clay. In a general way the major and upper portion is more or less completely dolomitized and to it the name Galena limestone is applied. The lower portion consists of an upper, non-magnesian blue limestone, and a lower magnesian rock known usually as the lower buff beds. All of these members are commonly found throughout the area of outcrop of the series as a whole. Except for the intervention of a few feet of shale, the lower buff beds rest directly upon the Saint Peter sandstone and maintain a quite uniform thickness of approximately twenty-five feet throughout the region. Above them is the blue, non-magnesian limestone. It has already been pointed out that the thickness and character of this member varies considerably in various portions of the field. In Allamakee county it reaches a maximum of 150 feet and is made up of alternating layers of shale and shaly limestone.* In Dubuque county it is rarely more than twenty feet in thickness. The Galena limestone, which reaches a maximum of 237 feet in thickness at Dubuque, is represented by less than fifty feet of strata in Allamakee county. At both extremes a thin bed of shale is found between the base of what is called the Galena and the top of the recognized Trenton. Careful tracing up the river indicates, however, that it is not the same shale from point to point but that each of the shale beds which in Allamakee county divide the Trenton series, in turn marks off the Galena from the Trenton as one travels south and toward lower stratigraphic horizons. Certain of the beds, which are usually particularly fossiliferous, can be

*Calvin: Iowa Geol. Surv., Vol. IV, pp. 75-78.

traced literally from the Trenton into the Galena. In general, however, when one passes from the non-dolomitized into the dolomitic rock, the shales disappear. The general conclusion already stated is inevitable, viz., that the difference between the Galena and the Trenton is not formational. It is also obvious that the rock has been dolomitized to an increasing depth toward the south, and that this increasing depth of dolomitization varies *parri passu* with a decreasing amount of shale in the formation. Further study shows that in each point the base of the overlying dolomite is separated from the underlying non-dolomitized rock by a bed of shale and that dolomitization proceeded from the top downward and was stopped at successively lower horizons toward the south as the various shale beds thinned out.

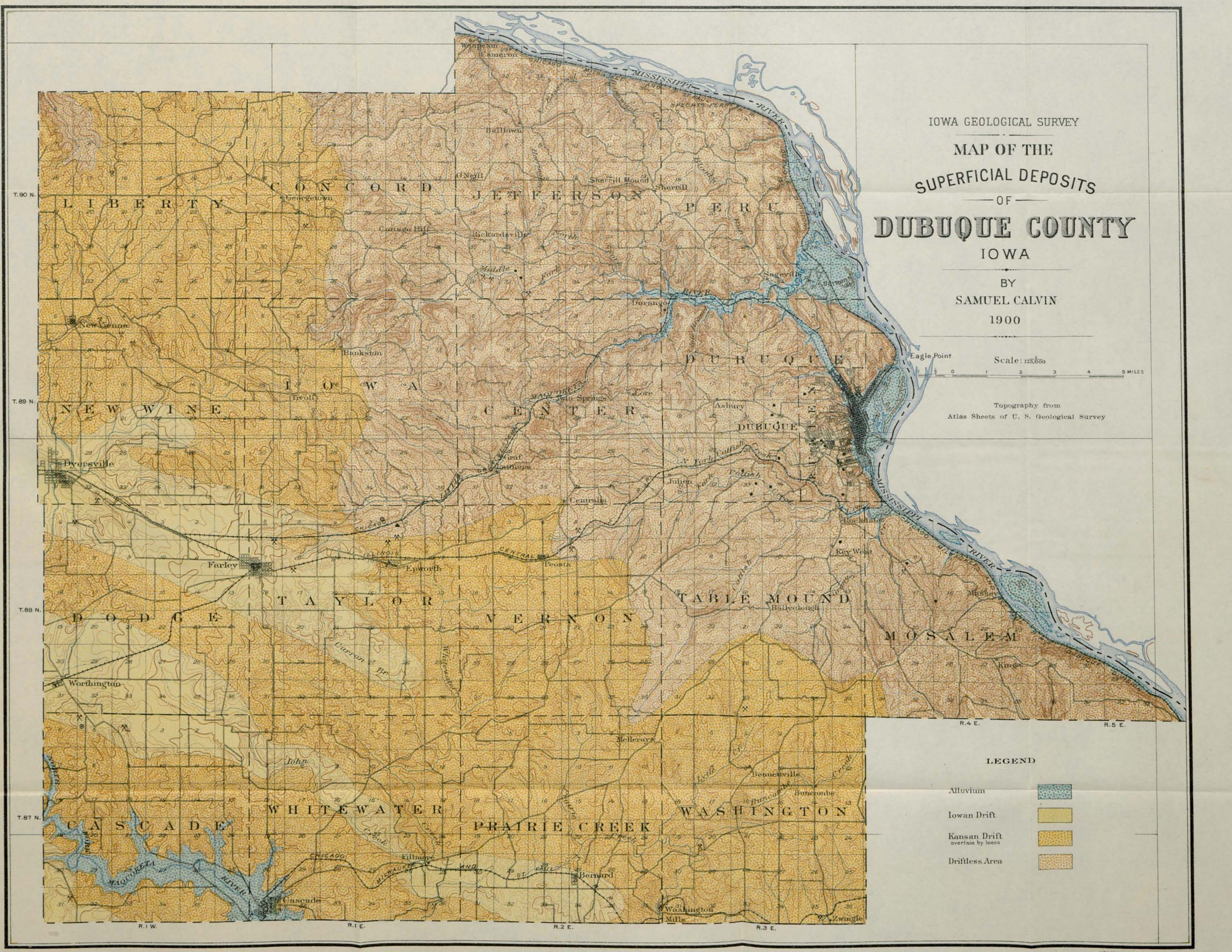
The older Archean and Cambrain land from which the material of the Galena-Trenton series was derived, lay undoubtedly to the north and east of the district under consideration. The major portion of the sediment deposited here came apparently from the north. The shales are made up of mechanical sediment. They indicate nearness to land and the progressively slighter southern extent of the later shale beds indicates merely the gain of the sea over the land and the pushing of the shore line to the north. Whereas at the beginning of the Galena as defined at Dubuque, the shore was so near the latter point that clay and fine mud could be deposited over the region, at its close the shore had retreated so far that mechanical deposition had almost entirely ceased, not only at Dubuque but over a wide region to the north. Chemical and organic agencies were accordingly prominent in the formation of these later beds. It remains to inquire in detail what these agencies were and how they acted.

Neither limestones nor dolomites are formed, with unimportant exceptions, through mechanical means. They must either be the result of primary or secondary chemical action.

Taking first the case of limestones, but little study is necessary to show that while it is possible that they may be formed by direct chemical precipitation from a saturated solution or by the action of springs, as a matter of fact most limestones seem to have been formed through various organic agencies. A large number of animals have the power of secreting lime from sea water to form the various hard parts of their bodies, and these shells and other remains, in part broken up by the waves and possibly recemented by percolating water, later perhaps recrystallized into a homogeneous mass, make up the bulk of known limestones. The limestones of the region under consideration afford, so far as can be discovered, no exception to this rule. It is further clear that they were formed within relatively shallow water since they were still within the reach of an occasional incursion of mud.

The rocks now dolomitized were manifestly deposited under somewhat different circumstances. It is clear that they were not within the limits of mechanical sedimentation to any appreciable extent. Certain considerations also make it clear that the rocks as originally deposited were not dolomitic, though not necessarily non-magnesian, and that the change to dolomite has been a secondary process. It is not intended, however to affirm that this change may not have followed immediately after the deposition or even have been in part contemporaneous with it, but merely that there was an appreciable, though not necessarily long, pause in the general process. The considerations upon which this is based are briefly as follows:

The uniform stoppage of dolomitization at a shale band when traced downward, is a striking, though not necessarily conclusive, confirmation of the main thesis. Shale is far more impervious than either limestone or dolomite, and the shale bed makes always a break in either downward or upward water flow. It thus exerts an important influence on all secondary reactions taking place in stratified rocks, though it does not have any determining value in the matter of primary sequence.


IOWA GEOLOGICAL SURVEY
MAP OF THE
SUPERFICIAL DEPOSITS
OF
DUBUQUE COUNTY
IOWA
BY
SAMUEL CALVIN
1900
Scale: 1/125,000
Topography from
Atlas Sheets of U. S. Geological Survey
LEGEND
Alluvium
Iowan Drift
Kansan Drift
overlain by loess
Driftless Area
LIBERTY
CONCORD
JEFFERSON
PERU
NEW WINE
IOWA
CENTER
DUBUQUE
DODGE
TAYLOR
VERNON
TABLE MOUND
MOSALEM
CASCADE
WHITEWATER
PRAIRIE CREEK
WASHINGTON
MISSISSIPPI RIVER
T. 90 N.
T. 89 N.
T. 88 N.
T. 87 N.
R. 1 W.
R. 1 E.
R. 2 E.
R. 3 E.
R. 4 E.
R. 5 E.
Dyersville
Farley
Epworth
Peosta
Cascade
Dubuque
Eagle Point
Key West
Rockdale
Worthington
Fillmore
Bernard
Sageville
Durango
Bankston
Centralia
Graf
Julien
Asbury
Balltown
Sherrill
Sherrill Mound
Georgetown
New Vienna
Bellevue
Buncombe
Bennetville
Zwingle
Washington Mills
Melleray
Ballyclough
Massey
Cottage Hill
Rickardsville
Luxemburg
Tivoli
New Wine
Mosalem
LITH. BY A. HOEN & CO. BALTIMORE, MD.

A shale bed might be a valid reason for dolomite above and limestone below if we believe the dolomite to be altered limestone, but it would be of no significance if we assume the latter to have been originally deposited as a dolomite.

The non-dolomitic rock is characteristically thin bedded, and the thin bedded rocks of definite horizons on the one side are represented by the thick bedded on the other. Either some change has taken place which has led to the obliteration of the bedding planes, and has given the rock a new and massive character, or for some peculiar reason these planes were never developed in the southern portion of strictly contemporaneous beds, though conspicuous in the same beds farther north. The most convincing evidence, however, of the essentially secondary nature of the dolomite is derived from the manner of preservation of the fossils in the two parts of the deposits.

It is evident, then, that a considerable portion of the magnesia now present in these rocks was not deposited as a carbonate, but that its change into this form is a later one. This does not exclude the hypothesis that a considerable portion of the magnesian carbonate may have been originally deposited as such. It is known that both magnesia and calcium are in solution in sea water in small but appreciable amounts, and it is believed that the magnesia may under certain conditions be deposited directly as a carbonate. Constantine Klement has shown by experiment* upon the action of solutions of magnesian salts on powdered aragonite and calcite that a mechanical mixture of magnesium and calcium carbonates could be produced. He subjected powdered aragonite crystals and coral to the action of magnesium sulphate in a concentrated solution of sodium chloride. Action began at 60° and increased to 91°, with a maximum yield of 42 per cent of magnesium carbonate, which, in the presence of calcium carbonate, gradually crystallized as a true dolomite. It

*Bul. Soc. Geol. Belge., 1895, 9, 3-23, Tscher Mitth., 1895, 14, 526-544; Abstract. Jour. Chem. Soc., LXX, II, 116.

is to be noted that these conditions would all be readily reproduced in shallow sea basins, such, for example, as the enclosed lagoons of atolls. This is in line with what has been actually observed in coral atolls.

In enclosed basins of sea water magnesium chloride is often in considerable excess over the sodium chloride.† The evaporation of the sea water tends to make the solution continually stronger, so that there is a constantly increasing tendency for the magnesia to enter into combination with the limerock which may be believed to form the basin of the pool in question, and to have been deposited mainly, as usual, through the action of living organisms. Soft, newly formed sediments may readily be believed to be particularly open to changes induced by the presence above them of relatively strong solutions, and Sterry Hunt has shown that a number of chemical reactions are probable, through which the change to dolomite can be brought about.

It is believed that in some such manner as this the newly formed non-dolomitized Trenton rock was changed into the dolomitized form now known as Galena. Chamberlin has shown that the beds in question were laid down in water so shallow as to be within the limit of wave action,* and while no such clear evidence has been observed in Iowa, certain breccias occur which are best explained by a similar hypothesis. It is also significant that the dolomitic Galena is followed and covered by the Maquoketa shale which is formed from mechanically derived sediment. Furthermore at the base of the Maquoketa is the bed of small pebbles already described. These show clearly the action of surface agencies, but the fact that no Archean material has been found among them indicates that the pebbles were in the main locally derived. All the conditions are just such as would be expected when the sea gradually disappeared over a wide, flat expanse

†Geikie, 3rd Ed., p. 412.
*Geol. Wis., Vol. IV, p. 409.

by simply drying up, and when sedimentation was resumed without great change in the altitude of the land.

The phenomena in hand seem, then, to be best interpreted upon the supposition that during the accumulation of the beds now known as the Galena the area was occupied by a broad, shallow, land-locked basin or series of basins over which evaporation was active. This evaporation necessarily had the effect of concentrating solutions which in normal sea water are dilute. That this action was discontinuous and that its operation was unequal at different times and in different parts of the area, is obviously the most reasonable supposition, and consequently at different levels and in different areas we may expect to find varying degrees of evidence of this sea water concentration. As a matter of fact this is true and there are all varieties, from the most perfect dolomite to limestone with but a small percentage of magnesia.

A detailed section of the Galena-Trenton series has already been given and it has been indicated that the lead and zinc ores are confined to this formation. Later the different ore horizons are noted but it seems important here to note certain features of the overlying formations.

Maquoketa.—The formation which immediately overlies the Galena is the Maquoketa shale or "slate" as it is commonly known among the miners. This is in large part a soft argillacous shale. It is a barren formation, no mines ever having been worked in it, nor have any important bodies of ore been found in it. In one or two instances only, in sinking through the slate, small pieces of ore a fraction of an inch in diameter have been found. In view of the fact that the shale is composed of mechanically prepared material, and that at its base pebbles of pre-existing rocks of various sorts are common, these bits of ore can be quite certainly considered to be adventitious in origin. The miners' conception of them as float is a good one.

The shale is not cut by any general system of crevices. Such cracks as occur in it are close set and of small extent.

Fracture in it has taken the form, as would be expected from its semi-plastic nature, of many small cracks rather than a few well developed ones such as mark the dolomitic beds. The shale accordingly is a practically impermeable horizon and cuts off the ordinary surface waters above from the limestones below. There is no general circulation of water down through the shale into the Galena limestone. The water which is found in the limestone comes from the collecting area over which the dolomite is itself exposed, or from those areas which, by the arrangement of the divides, shed surface water upon the area occupied by the Galena. The water runs over the slate rather than through it.

Niagara.—Above the Maquoketa is the great thickness of Niagara which, like the Galena, is dolomitic. There are, however, important differences. The Niagara is normally finer grained and does not seem to be as much cut up by crevices and caves as is the Galena, though it lies higher above the water level. The Niagara shows occasional traces of lead, though no paying mines have ever been developed in it. In Jones county, near Anamosa, at Clinton, and at Sherril Mound in Dubuque county, small quantities of lead have been found. In this particular, the formation is like the Oneota, in which ore has been found in small quantities at several points, though only the one mine at Lansing has ever been developed. So far as analyses of the rock are concerned, the Niagara is not notably richer or poorer than the Galena, and the absence of ore bodies may probably be considered to be due to some defect in the matter of concentration.

THE ORE DEPOSITS.

ORES AND ASSOCIATED MINERALS.

The ores found in Dubuque county include lead, zinc, a small amount of copper, and at least one notable deposit of iron. The latter will be separately treated, but the others may be considered together. Lead and zinc are the only minerals being actively mined at present. The following notes on the minerals occurring are revised from Dr. Leonard's report.*

The only ore of lead that is found to any extent in the Iowa mines is the sulphide, galena (Pb S). The carbonate, cerussite ($Pb\ CO_3$), is of rare occurrence, and is derived by alteration from the more common sulphide.

Galena (Lead, 86.6 per cent; sulphur, 13.4 per cent; Sp. gr. 7.4–7.6).—This mineral occurs, as a rule, in well defined cubes, which are joined together in masses of greater or less size, forming groups or aggregates of crystals. The corners of the cube are sometimes replaced by the faces of the octahedron, and this form may predominate until, in rare cases, the cubic faces have disappeared altogether. All the specimens observed from the mines directly about Dubuque were clusters of cubes unmodified, but the Galena from a section lying south of the city, as well as that from the Guttenberg mines, is crystallized in forms showing the combination of the cube and octahedron. From the last mentioned locality a few unmodified octahedrons were obtained.

The crystals seldom present bright metallic surfaces, the faces being dull and more or less corroded or coated over with some foreign substance. The miners have different names for the various kinds of lead ore. Thus the term "cog mineral" is applied to groups of good sized cubic crystals. When these are small the ore is called "dice mineral." When the sulphide occurs filling a narrow fissure, it is rarely well crystallized, and is then known as "sheet mineral," and when occurring in irregular masses it is called "chunk mineral."

The lead from the Iowa mines, like that from the other regions of the Mississippi valley, contains only a trace of silver, and is known as soft lead in contrast with the argentiferous ore of the western mines. More or less of silver is almost invariably present in lead ore, especially when the latter is

*Iowa Geol. Surv., Vol. VI, pp. 25-27.

found occurring in the neighborhood of metamorphic or igneous rocks. But the deposits found in undisturbed sedimentary strata commonly contain no silver except in very small amounts.

Dr. Otto Kuntze, of Iowa City, has recently brought to

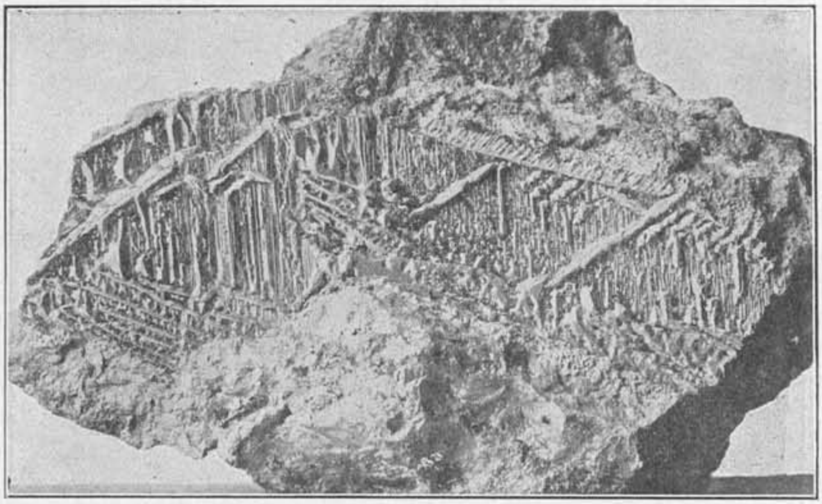


Fig. 54. Reticulated Galena. Three-fifths natural size, from collection of Dr. Otto Kuntze.

light some exceptionally good specimens of reticulated forms of Galena, one of which is illustrated in figure 54.

Cerussite (Carbon dioxide 16.4 per cent, lead oxide 83.6, or metallic lead 77.7 per cent).—This mineral occurs as a coating upon the sulphide and also at the Lansing mine in Allamakee county, in crystals lining small cavities in the galena. The ore from this mine is also frequently covered by a thin layer made up of numerous small, twin crystals of cerussite. Wherever the galena has been long exposed to the weather, as in the case of the float lead found in the soil, the carbonate supplies it with a white coating. In the formation of the cerussite, which is evidently a secondary mineral formed by the alteration of galena, the sulphide is first converted into the sulphate ($Pb\ SO_4$) and the latter, through the agency of water holding bicarbonate of lime in solution, is transformed into the lead carbonate.

Smithsonite (Carbon oxide 35.19 per cent; zinc oxide 64.81, or metallic zinc, 52 per cent Sp. gr. 4.30-4.45).—The zinc ores found in Iowa are the carbonate, smithsonite ($Zn\ CO_3$) and the sulphide, sphalerite of blende ($Zn\ S$).

The carbonate, or "dry bone" as it is commonly called, is by far the most common in Dubuque mines. It occurs in a variety of forms which may be described respectively as cellular masses, botryoidal coatings, earthy masses and small bodies impregnating the rock. It often bears a close resemblance to the calcareous tufa found about so many springs in limestone regions. Sometimes it supplies a coating for galena crystals, or it entirely replaces them and forms pseudomorphs. Several interesting specimens were seen in which fossils had been entirely replaced by the carbonate. One of these was a slab of smithsonite on which were several large gastropods, their substance wholly gone and the place filled by zinc ore, the outline being perfectly preserved. The carbonate contains, on an average, from 30 to 40 per cent of zinc, though some specimens run as high as 49 per cent.

Sphalerite (Zinc 67 per cent, sulphur 33 per cent Sp. gr. 3.9-4.1).—The sulphide, the "black jack" of the miners, is much less abundant in the Iowa mines than the smithsonite. This is doubtless due to the transformation that has taken place, by which the former was changed over into the carbonate as will be explained later. The blende commonly occurs in compact layers or masses, and does not exhibit any crystal form. But crystals are by no means rare, being found in cavities in the limestones or in geodes. The sulphide is of a very dark, almost black, color and quite opaque.

The zinc silicate, or calamine, was not observed in any of the mines, though it probably exists in small quantities along with the smithsonite.

The change of the sulphide to the carbonate seems to have been very extensive, and the latter is probably all of secondary origin and derived from the blende. Several facts indicate that the latter has been the source of the carbonate.

(1) Specimens are very common in which the outside is dry bone, while the unaltered interior is composed of the sulphide. (2) In the lower levels and where water abounds the ore is the sphalerite. This is the universal rule and would seem to be owing to the fact that the lower deposits are not subjected to the atmospheric agencies at work nearer the surface. The chemical changes that have taken place in the zinc blende are probably as follows: The sulphide ($Zn\ S$) in the first place became, by oxidation, the sulphate ($Zn\ SO_4$), which is a very soluble compound; then through the agency of the alkaline and earthy carbonates in solution in the circulating waters, the zinc sulphate would be changed into the carbonate and redeposited in the crevices. Where the blende is under water it is little affected by oxidation and hence remains unaltered.

An excellent example of the alteration of zinc blende to dry bone is illustrated in figure 55 from a photograph of a specimen given to the survey by Dr. H. G. Knapp. The black jack is found here in pieces almost entirely surrounded by the carbonate, and the ribbed appearance of the latter is apparently due to the original cracks in the black jack, along which alteration began. Analyses of the two minerals from this specimen gave the following results:

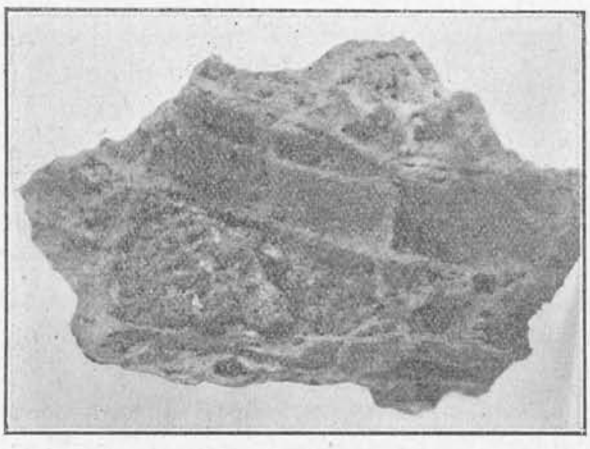


Fig. 55. Blende altering to dry bone. The reticulated dry bone shows surrounding the unweathered blende.

Black Jack..............Zn, 52 per cent; ZnO, 64.80 per cent
Dry bone..............................ZnO, 57 24 per cent*

A variety of different minerals occur in the same crevices along with the lead and zinc, and these deserve more than a passing notice, since they serve to throw light upon the origin of the two associated metals.

Copper.—Copper has been found at a number of points in the Upper Mississippi lead region, and was at one time mined and shipped from near Mineral Point, Wisconsin. It has never been found in extensive bodies, however, and has not previously been reported from Iowa. The copper found here occurs as stains of malachite and azurite on the carbonate zinc ores; the whole corresponding essentially to green calamine or aurichalcite. When pure this mineral carries 29.17 per cent oxide of copper, 44.71 per cent oxide of zinc; 16.19 per cent carbon dioxide, and 9.93 per cent of water. Specimens obtained from Messrs. Hird's mine near Center Grove, Iowa, showed 4.76 per cent metallic copper.

Pyrite and Marcasite (sp. gr. 4.95-5.10).—These are very common in the workings and are the "sulphur" of the miners. They have the same composition with a ratio of 46.7 of iron and 53.3 of sulphur, but crystallize in different systems; pyrite being isometric, and marcasite orthorhombic. The latter is commonly whiter than pyrite. They do not occur in well defined crystals so much as in crystalline aggregates of irregular form.

At the mine of the Dubuque Lead Mining company on the Ahern ground, however, the pyrite was found well crystallized. The limestone has here been much affected by dissolving agencies and is so filled with cavities that the rock has somewhat the appearance of a breccia cemented together by iron pyrites. Instead of the more common cube the mineral here occurs in perfect octahedrons sometimes modified by the faces of the cube. Penetration twins are also of frequent occurrence. The crystals vary in size from one-fourth to three-fourths of an inch. When exposed to the air these sulphides

*Equivalent to 88.33 per cent zinc carbonate.

readily oxidize and change over into limonite. This alteration is finely illustrated in a specimen from the Lansing lead mine. The interior is made up of marcasite while on the outside this has undergone a chemical change and a coating of limonite one-fourth of an inch thick has been formed. The same specimen is covered on one side by Galena and on the surface thus protected the marcasite has suffered but slight alteration, showing that the changes took place after the deposition of the Galena on the iron sulphide. Otherwise there would seem to be no reason why the limonite should not be of the same thickness on all sides.

Limonite. (Ocher Rust.)—This is a hydrated oxide of iron and is found in large quantities in the ore-bearing crevices where it was formed by the oxidation of the pyrite and marcasite. This alteration process has gone on so extensively that a large part of the original minerals has been changed into the iron oxide. It is usually impure and earthy, imparting to the clay and other crevice material a brown color.

Wad. (Manganese Dioxide.)—This mineral occurs as a black earth in several of the crevices at Dubuque; notably the black crevice. Manganese also forms a common accessory constituent in the Durango iron ore.

Calcite and Aragonite.—These are the most common of the associated minerals, occurring abundantly throughout the region. The following varieties were observed:

1. Well crystallized calcite; the "tiff" of the miners.
2. Fibrous variety or satin spar.
3. Lamellar, pearly white variety or argentine.

The two latter are closely associated and are found together in the same stalactites.

The crystallized calcite forms fine crystals and groups of crystals often of much beauty. A very common occurrence is the combination of the scalenohedron (R 3) with the rhombehedron (R) and the prism of the first order (P). But more complex combinations are found. Thus one specimen showed the prism of the first order and three scalenohedrons, two positive (R 3 and $\frac{1}{4}$ R 3) and one negative, the latter beveling the acute angles of R 3.

Satin spar and argentine are associated in some crevices about five miles south of Dubuque (Tp. 88 N., R. III E., Secs. 16 and 17).

Some of these "spar caves" have been productive crevices from which large quantities of ore have been taken, while others are barren and filled to a greater or less extent with clay. The Galena limestone in this locality is cleft by a complex system of extensive fissures which form a labyrinth of underground passages, and in certain portions contain large deposits of calc spar lining the top, sides and bottom. The deposition of lime carbonate does not go on extensively where there is more than forty feet of limestone above the cap rock. One remarkable feature of these "caves" deserves more than a passing notice. The floor, which is formed of a layer of calcium carbonate 6–10 inches thick, is suspended in the top of the crevice. This is well shown in the accompanying figure (Fig. 56). The floor was evidently formed when the clay was at that height in the fissure and was deposited on top of this impervious material. Later the clay has settled, leaving the crevice open beneath the lime deposit; sometimes this settling amounts to as much as thirty or forty feet. The floor of the

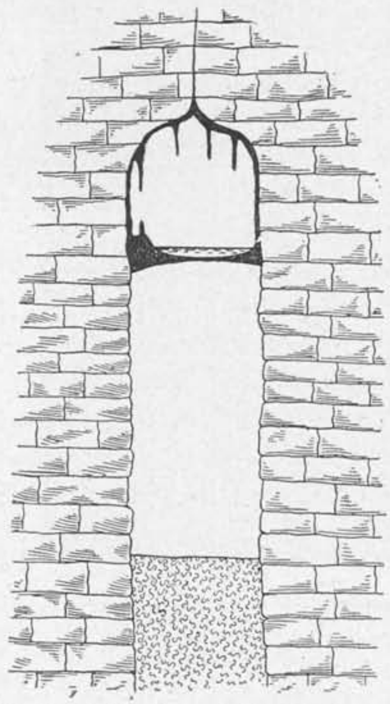


Fig. 56. Section through Kembling's spar cave suspended in top of crevice, stalactites and miniature lake.

cave thus forms a horizontal partition across the top of the crevice. It may be connected with the roof by several columns formed by the growing together of stalactites and stalagmites. On this floor is sometimes found a clear pool of water.

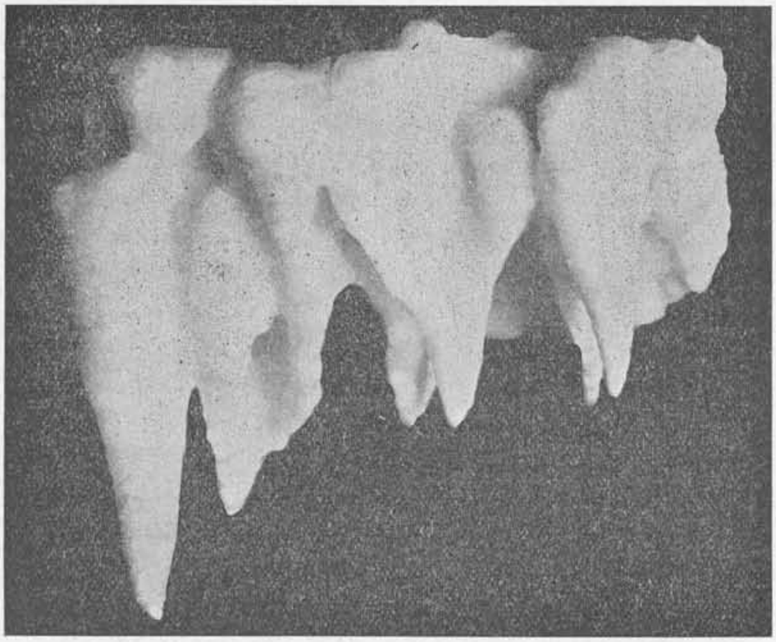


Fig. 57. Group of Stalactites from Kemling's cave, south of Dubuque.

The satin spar has a fibrous structure, silky luster and is colorless or white. It is made up of delicate acicular crystals of aragonite. The argentine (schieferspath) has a pearly luster and is composed of more or less undulating lamellæ of pure white color. The specimens found here agree well with the descriptions given by Dana and Tschermak. Several different forms of stalactites occur: (1) Those specimens which are pearly white on surface of fracture, with a silky lustre due to the radiating fibers that form a velvety surface of great beauty. This variety occurs in bunches or clusters of twisted and gnarled stem-like forms. (2) Stalactites proper; formed of radiating fibers. In cross section these have a vitreous luster, and on the surface are (a) either covered with a fine white powder, and show no luster, or (b) the outer surface is formed of little rhombohedrons and has a silky luster. They are white or colorless; opaque or translucent.

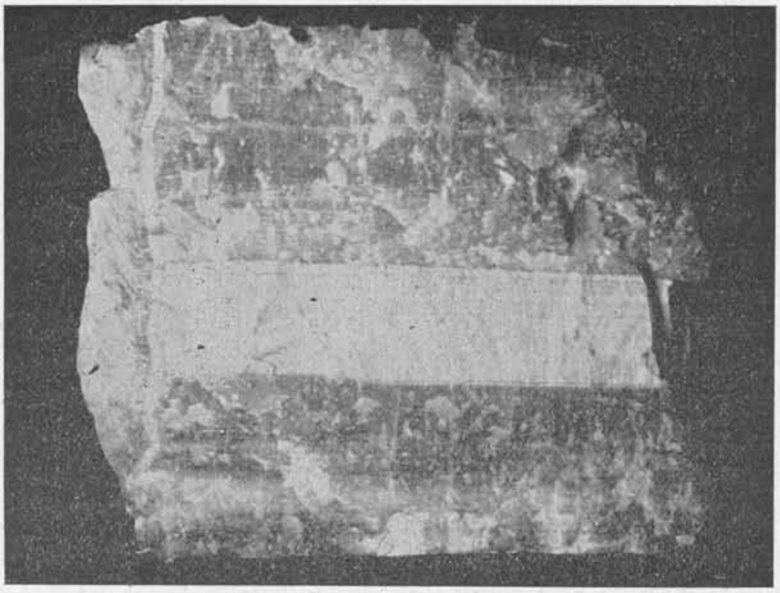


Fig. 58. Specimen showing band of pearly argentine in transparent calcite from floor of Kemling's cave, south of Dubuque.

Other stalactites have a concentric banded structure and possess several points of unusual interest. Beginning at the center they show (1) a crystalline or granular core, often displaying bright rhombohedral faces; (2) a thin band of clay, apparently wanting in some cases; (3) pearly white lamellar calcite (argentine); (4) a band of clay; (5) a fibrous aragonite; (6) an outer surface composed of little rhombodedrons.

Several features in the structure of these stalactites deserve special notice. There is every indication that the crystalline core was once fibrous, but this structure has mostly disappeared, especially in the larger specimens, and is replaced by the rhombohedral cleavage. In the smaller forms the transition from the radiating fibrous variety to the crystalline aggregate of rhombohedrons can be traced. The long acicular crystals become less and less distinct, though traces remain visible after the rhombohedral form makes its appearance. Recrystallization has taken place and the molecules have rearranged themselves to conform to the interior structure of the rhombohedron; or, in other words, they are identical with the latter crystal form in all but external outline and this has been prevented from developing, showing itself only on cleavage faces. Another strong indication that this granular core was once fibrous is found in the fact that this latter structure is the common one in all these caves. The small forms all show the radiating fibers, but as they increase in size alteration has taken place.

Another point of interest relates to the band of pearly lamellar calcite occurring between the granular, crystalline core and the fibrous external layer. The white lamellæ form concentric rings in marked contrast to the radiating fibers associated with them. Occurring on both sides of the argentine in most cases if not in all, there is a thin band of clay. It is this that doubtless marks the suspension of deposition for a time, and when redeposition commenced the conditions were so changed that a different variety was formed.

The rhombohedrons forming the surface while the interior is fibrous, also deserve notice. They occur on the larger stalactites but not on the delicate branch-like forms. The exterior of the latter owes its silky luster to the innumerable fibers of which it is composed. They frequently form delicate cotton-like masses covering the outside of the satin spar.

On the majority of stalactites, however, the crystal aggregate of rhombohedrons occurs. They may have been deposited after the radiated interior was formed, but they seem to be due rather to the alteration or recrystallization of the fibrous mass, as in the case of the granular core. The conditions under which the fibers were formed have changed, and there has been a corresponding change in the crystalline condition of the calcium carbonate.

The satin spar occurring in the large branch-like clusters is notable on account of its great beauty and rarity. As it

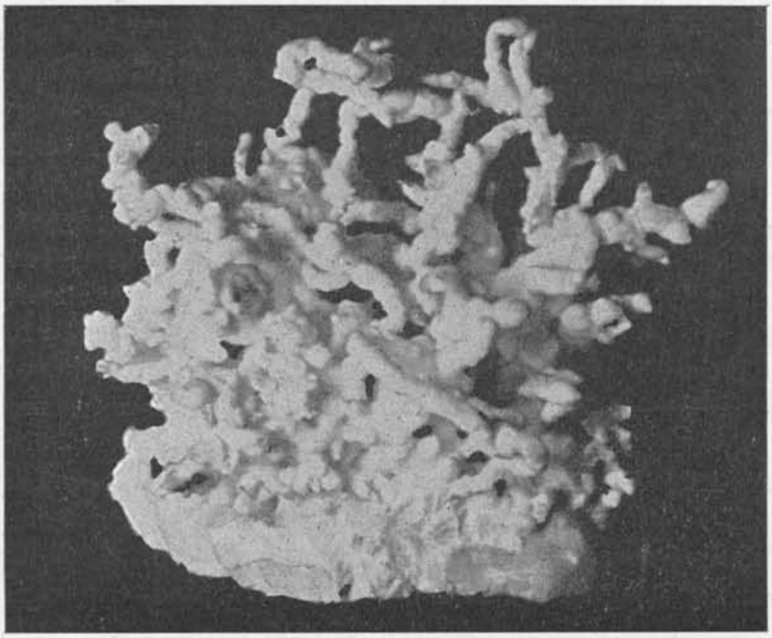


Fig. 59. Satin spar showing twisted stem-like forms. Linden's cave, south of Dubuque.

hangs suspended from the roofs of the caverns it resembles at a distance branching coral, but near at hand the twisted and gnarled stems with their beautiful silky luster bear no likeness to the polyp structures.

Gypsum.—This mineral is not of common occurrence in the region under view. It is, however, occasionally found in the crevices along with the ores. There is a very unusual occurrence of crystallized gypsum, or selenite, in the "spar caves." The specimens are found on the top of the clay forming the floor. The selenite occurs in very long acicular crystals. These needle-like forms are composed of two individuals, whose twinning plane is the orthopinacoid (∞ P $\bar{\infty}$), and are greatly elongated in the direction of the vertical axis. The faces which appear are those of the clinopinacoid ($\infty P \overline{\infty}$) and unit prism ($\infty P$).

Two cleavages are well shown: (1) The most perfect is parallel to the clinopinacoid; (2) there is a second good cleavage parallel to the negative pyramid ($-mP$). The extent to which these twin crystals have been elongated is remarkable. One specimen had a length of 6½ inches, with a width of less than ¼ of one inch. Another was 5¼ inches long and extremely slender, being less than $\frac{1}{16}$ of an inch wide and perfectly transparent.

Dolomite (Sp. gr. 2.8-2.9).—Crystallized dolomite is not common, and when found usually lines the sides of small cavities in the limestone. Since the latter is highly magnesian, it might be expected that dolomite would more frequently occur, but its rarity is doubtless due to the greater solubility of the magnesian carbonate. On this account it would remain in solution while the lime carbonate was deposited.

Barite—Crystalline masses of heavy spar are occasionally found in pockets or druses in the Galena limestone. The Sunflower crevice has produced an exceptional amount of this mineral, though it is not uncommon throughout the region.

THE ORE BODIES.

The ores mined at Dubuque include Galena, or lead sulphide, to which locally the term mineral is commonly restricted, zinc carbonate usually called bone or dry bone, and zinc sulphide, which is known as jack. In Wisconsin the sulphide of iron is also mined, but while it occurs in the Iowa mines it has not as yet been marketed. To the miners is known as "sulphur." These ores occur in a considerable variety of forms ranging from simple vertical sheets to widely disseminated deposits. There seems to be no close association of particular ores with a particular form of ore body, and only a general association of a particular ore or particular form of ore body with particular stratigraphic horizons. Such associations as have been noted will be described later. Considering first the diverse forms of ore bodies it is seen that they may be grouped into *a* vertical sheets, *b* horizontal sheets or "flats," *c* "pitches," *d* disseminated bodies, and *e* cave deposits.

Vertical sheets.—The simplest form of ore body occurring in the region is the familiar vertical sheet similar in all essential particulars of form to the vein deposits of other regions.

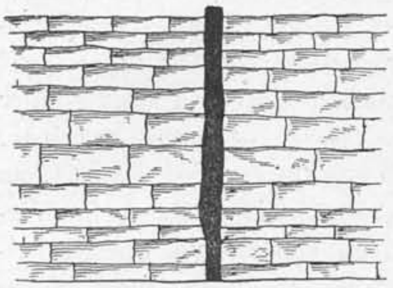


Fig. 60. Vertical sheet of galena in McPoland and Basler mine.

A vertical sheet, in this case carrying lead ore, is illustrated in figure 60. This sheet was sketched in the McPoland and Basler mine in West Dubuque in 1899, but similar sheets have been followed in the Avenue Top and a large number of other well known mines. The simple sheet of mineral, here one-half to three-quarters of an inch thick, lies between undisturbed dolomitic walls. These walls have weathered to a loose dolomitic sand for a distance of three to eleven inches on either side of the sheet. There are no selvage bands, no signs of faulting nor any crustification* such as is usual in the deep seated veins of the west. The genesis of the deposit is simple and obvious. The narrow crack in the rock became filled, by means later discussed, with galena, and since that occurred the dolomite has weathered as shown. If the circulation of underground waters had removed a portion of the dolomitic sands, the crevice would have been found partly open and partly filled with loose sand mixed with small chunks of mineral. This is a very common form of occurrence in the region.

As in all mineral veins these vary in richness and character from point to point. The sheet of mineral pinches out in all directions, thickens and thins, and when its dimensions are considerable the lead plays out and the zinc takes its place on the same level, or at different levels on the same

*Posepney; Trans. Amer. Inst. Min. Eng., Vol. XXIII, p. 207.

vein. In general, near Dubuque vertical sheets are more common in the north-south crevices. The east-west crevices, opening out toward the main drainage lines, and hence offering a freer course for underground waters, are usually broader, and if the mineral ever occurred in them in vertical sheets this form is now usually destroyed. The north-south crevices, at Dubuque, are rarely important producers, but often lead to important deposits where they intersect with east-west crevices.

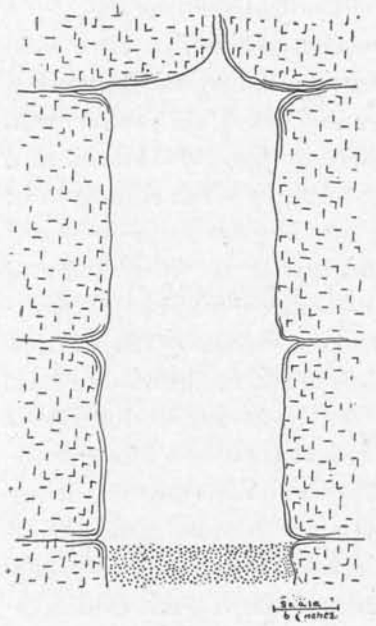


Fig. 61 Sketch of a quartering crevice in Leven's mine. Drawn to scale.

Flats.—This form of deposit has been extensively worked in Wisconsin, but has not yet been developed in any large way west of the river. In the flat the ore has the position of a blanket vein and runs off in a horizontal sheet parallel to the bedding. It is a most valuable form of deposit, as it allows the easy working of a large amount of ore. The flats so far developed in the region have not, usually, any great thickness, three to eighteen inches covering all but a few of the beds. In general the flats are found best developed in the lower portions of the Galena formation, and they show zinc blende, rather than lead or dry bone. The latter minerals occasionally tend to run off into flats in the upper levels, but no extensive flats of this kind have yet been found, nor are they to be expected. The flats

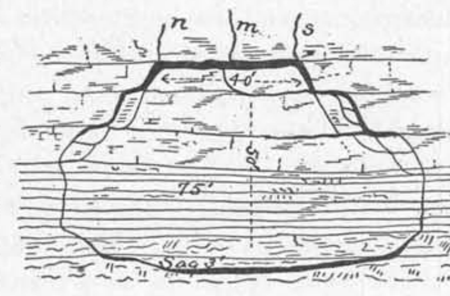


Fig 62. Sketch showing relations of flats and pitches after Chamberlin.

are developed along stratification planes, and seem to indicate that at certain horizons the mineral-bearing solutions found it easy to wander out laterally and form sheet deposits. They are not believed to represent here original interbedded deposits.

Pitches.—This form of deposit was discriminated by Chamberlin,* who very correctly considered the flats and pitches as simply different phases of one form. There is, however, some practical convenience in studying them separately. The relations of the flats and pitches are shown in figure 62 redrawn from Chamberlin's figure of the Roberts mine at Linden. It represents the usual development of the form except in the presence of three vertical crevices above instead of one. The pitches are usually relatively short and represent merely the arms by which vertical sheets are connected with flats. The ore body does not change direction with a simple right angle but by a series of steps as shown in the figure. A good example of a pitch in the Dubuque mines is the Alpine ore body. Pitches, with the flats, are usually found low in the Galena formation. They represent the normal verging off of a vertical fracture as it reaches a series of beds of different resistance, and Chamberlin has shown that pitches are usually developed in synclines. While occasionally a pitch is found showing a single arm, the double arrangement is more common and if a vertical east-west sheet be found pitching to the north, it may usually be assumed that there is a corresponding pitch of ore on the other side to the south.

Disseminated ore bodies.—So far as present development has gone, no large bodies of disseminated ore, such as are worked in southeastern Missouri, have been found. Nevertheless the wall rocks in many of the crevices show a certain amount of disseminated ore. In the Spring street or Fourteenth street, the various levels show a large amount of ore carrying dry bone to as much as 20 per cent. In the Bush, Alpine, and

*Geol. Wisconsin, Vol. IV, pp. 439-480.

Avenue Top there are large bodies of ore mixed with rock. In the mine formerly worked on the Ahern ground, the lead was found in small pieces scattered through the dolomite and could only be removed by jigging. The recently developed black jack deposits in the Pike's Peak country are really dis-

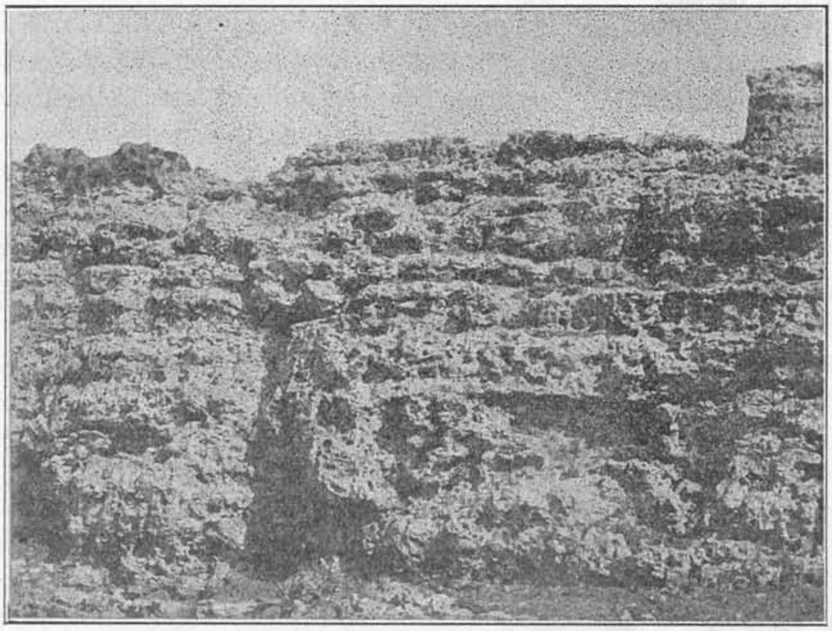


Fig. 63. Weathered surface of Galena limestone near Rockdale.

seminated. Wherever, in fact, the rock has been broken or rendered porous by solution there is a probability of disseminated deposits. The disseminated ores so far uncovered, aside from cave deposits, seem to represent impregnation of rocks rendered porous by solution rather than by fracture. In figure 63 the character of a weathered face of dolomite is excellently shown. The rounded cavities are evidently the work of solution and correspond to those described by Bell.* To a certain extent similar faces occur along the underground crevices, and the underground waters have penetrated

* Bul. Geol. Soc. Amer., Vol. VI, pp. 297-304.

the side walls so that the rock is similarly open for some distance from the crevice, but of course to a decreasing degree. In the case of the disseminated ores these openings have been later filled by the ores. In instances small glode like cavities lined with ore are found some distance from the crevice walls in apparently barren rock. The absence, up to the present time, of milling facilities has made it impracticable to work anything except the richest and cleanest ores. As a result disseminated ore bodies have not been looked for. The prospects of locating and mining these is one of the most hopeful lines of development in the district. In Missouri ores carrying 10 per cent jack or 5 per cent of Galena, and in times of high prices those carrying even smaller percentages, are mined and milled at a profit; and it can hardly be doubted that ores of this grade are to be found at Dubuque in considerable quantity.

Cave deposits.—The cave deposit is the one in which most of the larger and richer bodies of ore so far mined in the region have been found. In the early days of mining it was the dream of every miner to "break through" and find a cave which in his fancy was always lined with great crystals of glittering galena. Enough caves of this character have been found to lend color to all such dreams, for the Stewart's cave, Dubuque's cave, Leven's cave and others were all large producers. Some of them will be more particularly described later.

The caves are evidently but large developments of the crevices and openings. They are usually formed when several crevices come near together. The ore occurring in them is either attached to the walls, sometimes lining them as calcite or quartz so commonly lines geodes, or mixed with the loose dirt and rock in the bottom. In either case a large amount of ore is obtained with very little effort. The caves are occasionally of notable extent. In west Dubuque there is an area so cut up by open labyrinthine passages below ground and so full of water that it is known as the McPoland pond. On one occasion a small skiff was taken down a shaft and used in exploring this ground. It is believed that if the water could be drawn off large bodies of ore would be uncovered.

The caves are usually rich in mineral for the obvious reason that within them is accumulated all the ore originally in all the rock cut out to form them. They are, too, the meeting place of waters flowing along many crevices, so that precipitation is apt to be unusually active. They expose a large wall surface to the action of the forces which produce lateral segregation and accordingly nests of ore or even sheets are commonly found along their roofs or sides.

Chimneys, which are common along the crevices and which usually yield important amounts of ore, are incipient caves. All gradations can be found between the narrow vertical ore shoot which forms the typical chimney, and the great open cave. Usually the chimneys are full or partially full of broken rock which has tumbled in from the sides, and the ore is found cementing these pieces of rock. Dry bone is found largely in chimneys since it is a secondary deposit.

FORMATION OF CREVICES.

The earliest ores worked at Dubuque were the vertical sheets, and from their likeness to veins as mined in other regions they were called veins. Later, as the local peculiarities of the region became better understood, they came to be called crevices. Whitney invented for them the name of gash veins.* He defined the class as intermediate between segregated and true veins. Like the latter they occupy pre-existing fissures, but they are of limited extent and are not connected with any extensive earth movement. They are usually confined to one formation, being cut off below at any change in either the mineralogical or lithological character of the rocks. Whitney was inclined to consider them as genetically distinct from true fissure veins and states that the "origin of

*Metallic Wealth of the United States, pp. 48-49. 1854.

this class of fissures, must in all probability, be referred to the contraction of the rock caused by shrinkage, either while gradually undergoing consolidation, or from the effect of long exposure to somewhat elevated temperature." It now seems probable, however, that the difference between gash and fissure veins is one of degree of development rather than of genesis. The Dubuque veins were Whitney's type of gash veins and even a slight study shows that it is out of the question to assume that the rocks here have been subjected to "elevated temperature." A study of the crevices also convinces one that they cannot be referred to shrinkage as that term is now applied to rocks. Shrinkage could properly be assumed to be the origin of such fissures as are commonly known as mud cracks, but is not to be lightly assumed in connection with any other form of cracks in sedimentary rocks. Mud cracks are most frequently formed in unconsolidated rocks and have rarely any general relation to each other over wide areas.

The crevices at Dubuque were evidently formed after the rock was dolomitized and had become, essentially, as firm as now. The great shrinkage, 12 per cent, which took place in the change of the limestone to dolomite does not express itself in these cracks apparently, but in the large number of small cavities which distinguish even hand specimens of the Galena phase from that of the Trenton.

The crevices at Dubuque bear definite relationships to each other. The major crevices run very nearly east-west. They are crossed by a second set at almost exactly right angles, while a third set of minor crevices come in at nearly 45°. It is not so much that the cracks are at right angles, which is significant, but the major crevices are closely parallel to a series of low, broad folds which cross the region. The most pronounced of these folds is one already noted as having its crest cut by the river at Eagle Point.

When Whitney worked in the region joints, fissures and folds were considered to be radically different sorts of things.

They are now believed to be but diverse results of one general phenomenon—deformation. The parallelism between the major crevices of the region and the most pronounced folds strongly supports this theory. All the phenomena indicate that at some time later than the consolidation of the beds the strata were subjected to a certain amount of strain, and in their effort to accommodate themselves to this strain they were in part slightly folded and in part were cracked. When a rock or body of rock is subjected to stress this tends to relieve itself by a change of form or of dimensions. All rocks are under more or less strain, and even relatively strong rocks, if merely unequally supported,* tend to accommodate themselves to the various stresses to which they are subjected. If a rock be homogeneous it acts as a unit, but if there be differences in density or strength the various stresses are deflected from point to point. If the rock be soft and plastic, as is true of much the larger portion of the Maquoketa shale, the strain is accommodated by flow rather than fracture; that is, the individual particles of the rock move rather than great masses of rock itself. If the rock be thin bedded, and if, furthermore, its character change from bed to bed, as is true of the Trenton limestone, particularly when interbedded with shale, the stresses act on smaller blocks of rock, and deformation takes the form of numerous small fractures. It is very common to find the Trenton broken up into a large number of small blocks rather than in solid ledges. When, however, the rock is homogeneous, firm and of low elasticity, stresses are resisted for a longer time, and are ultimately relieved by great cracks extending, perhaps, for miles. The same amount of deformation may thus be accommodated in different ways in the rocks of the same section. Van Hise has shown that one rock may be so squeezed as actually to flow under pressure, while another, under the same conditions, is merely broken.†

*Iowa Geol. Surv., Vol. VIII, pp. 378-379.

†Van Hise: Sixteenth Ann. Rept. U. S. Geol. Surv., pt. I, p. 601.

The Galena limestone is a very massive formation. It is thick bedded, and the bedding planes themselves are not marked by any notable amount of shale or other foreign matter. The rock is of low elasticity. The formation is of considerable extent and of some thickness. This formation has been subjected to certain stresses, and these stresses have been relieved by the cracking of the rock. There seems to have been very little displacement, either vertical or horizontal, though there are well authenticated cases of a certain amount of faulting,‡ and nothing is more common in the mines than tipped blocks. The latter are, however, due to secondary settling and can be clearly shown, in most cases at least, to be due to the washing out of material below. They are local phenomena of no general significance, and are more common in the larger crevices.

The instances of horizontal faulting which Jenny mentions* seem to be merely the common phenomena of one crack shifting its course when crossing another. Stress, for example, develops the cracks *a–b* (figure 64) but when this crosses *c–d* the rock proves to be a little stronger and so the stress between *c–d* and *e–f* is relieved along the line *g–h*, parallel to the original direction but a short distance away. After crossing *e–f* the stress may be relieved along the original course forming the crack *i–j* or it may take any near parallel course, *k–l* or *m–n* for example. The latter will be much more likely to happen if the force which produces the crossing crack be later in time and come at a slight angle to the original force. In general the two sets of cracks

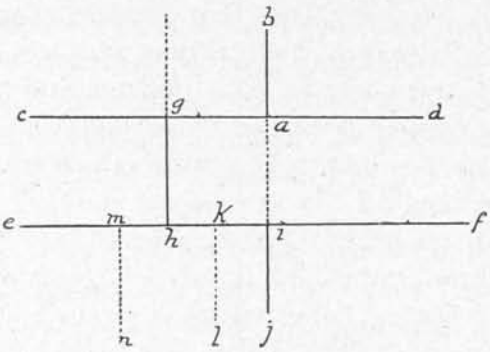


Fig. 64. Diagram illustrating apparent horizontal faulting.

‡Blake: Trans. Amer. Inst. Min. Eng., Vol. XXII, pp. 621-634.
*Trans. Amer. Inst. Ming. Eng., Vol. XXII, p. 208.

are of practically contemporaneous origin, as a stress acting through a homogeneous body tends to relieve itself by two planes at right angles. It is not necessary to assume a horizontal faulting to explain such phenomena as are here described, and in fact such an explanation requires much better evidence than has yet been found to support it. The phenomena are simply more striking instances of a common condition. In the Dubuque region, as elsewhere, the main crevices or cracks, while following the same general course, are not strictly parallel. They cross at low angles and at these crossings one or the other of the two crevices is apt to be slightly deflected. For example, *c-d* (figure 65) in crossing *a–b* is deflected slightly from the straight line *d–f*. Yet there has been no faulting. The rock walls on either side of *a-b* correspond directly. The stress tending to produce the fracture *c–d* has merely been relieved for a portion of its course by the nearly parallel *a–b*. Instances of such change in the direction of crevices are common and will be illustrated in describing the mines.

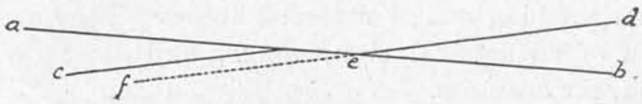


Fig. 65. Diagram illustrating relief of stress along a nearly parallel pre-existing crevice.

In the study of deformation, faulting and kindred topics, it is important to keep in mind that the appearance of great deformations is sometimes produced in rocks which have really been very little disturbed. An excellent example of this occurs near Specht Ferry and is illustrated in figure 66. Apparently the figure illustrates a shearing plane in horizontal rocks and when first seen was thought to mean a considerable amount of deformation. Close study has shown, however, that the lines of stratification pass directly across the shearing plane without displacement. There has been no arrangement of particles due to intense lateral pressure, no repeated faulting along closely parallel planes, nor any of the phenomena for which shearing usually stands. It is merely an instance of a large number of closely parallel vertical cracks, and there has been no displacement. Such an exposure, if found in a region of disturbed rocks, would probably be used as evidence of great dynamic movements, but in this situation it can not be so regarded.

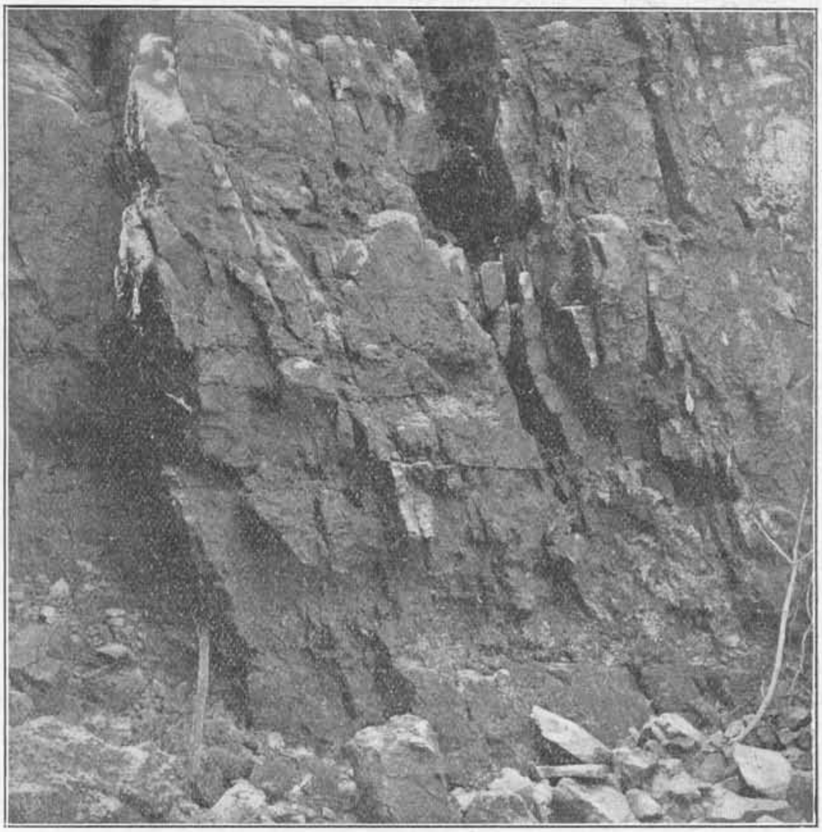


Fig. 66. Shearing in Galena limestone near Specht Ferry.

The ore bearing rocks of the Dubuque region are essentially undisturbed. The low folds found in the region are simply the expression of such slight earth movements as have probably taken place in all regions. The exceptional development of the crevices is due to the inelastic and homogeneous character of the rock which has allowed the formation of single crevices, or bunches of closely parallel crevices, such as the Timber range, which is known to extend in a fairly constant direction for a distance of five miles and more.

As already stated the major crevices have an essentially east-west direction. They are crossed by a second set at right angles, and a third set is occasionally encountered crossing at 45°. The crevices of any one set are not exactly parallel and may cross each other at low angles. The ore bodies are more commonly found at crevice intersections, so that the tracing of the crevices is quite important. Most of the large crevices have been worked at various times, and can be followed across the country by a line of old shafts. Beyond such a line they are usually located by taking the bearing of the crevice line and projecting it. Many of the crevices have been opened up at intervals over a length of one or two miles, and several are known for more than five miles of their course.

ENLARGEMENT OF THE CREVICES.

If the ore bodies simply filled in the original crevices, the amount of mineral would be quite inconsiderable. In instances where a simple sheet of undisturbed mineral occurs, the sheet is usually quite thin. A half or three-quarters of an inch is common, and in most of such crevices the ore body is not more than a few inches in thickness. The larger number of the mines, however, work much larger ore bodies, and the crevices, particularly at those horizons at which "openings" occur, are normally much wider. In a large number of mines the openings are from eighteen inches to four feet in width. Openings ten and twelve feet wide are not uncommon, and the Levens and other famous ranges are in places open from from thirty to forty feet in width. The Stewarts cave, more particularly described later, has a width of seventy-two feet. When, however, a crevice exceeds ten feet in width it is usually due to the coming together of nearly parallel crevices.

Manifestly there has been some agency at work cutting out and broadening the original cracks in the rock, which may fairly be assumed to have been at first quite narrow. A little study shows that this widening of the crevices has quite certainly been done by the circulation of underground water.

When rain falls upon the earth a portion of it runs off over the surface, a portion is evaporated by the sun's heat, and a portion sinks down through the soil and into the rock. This latter portion reappears at some lower point as a spring, or comes out in a line of seepage on some hillside. All rocks are more or less porous, and water finds its way through all of them, but with very greatly varying facility. Some rocks are so nearly impervious that water tends to collect along the upper surface and run off over, rather than through them. In this immediate region, for example, very little water passes through the shale, which overlies the Galena limestone, and wells usually obtain a lasting supply at the base of the drift and on top of the so called slate. Other rocks, such as the Saint Peter sandstone, are so open and porous that water passes through them readily, so much so that the whole of the rock is usually full of water. When the underground waters reach a crevice or crack they tend to follow along it just as the surface waters follow along valleys. Indeed, back of a spring there is a ramifying series of lines of drainage in the rocks corresponding in many particulars to the surface streams below the various springs. As the waters flow through the cracks they cut away the rock on either side. The action here is, however, quite different from that of surface waters. The latter do most of their cutting mechanically; that is, the bits of rock and sand carried by the stream rub and cut away the rock on either side and on the stream bottom. Underground waters rarely move with sufficient velocity to give them much erosive power, and their action is mainly chemical.

Surface waters are charged with certain proportions of various salts and acids, notably with carbonic acid gas. In the presence of this gas limestone is soluble in water to the extent of about one to 1,000 parts. In the course of their journey through the rocks the waters become charged with various other solvents and thus exert an important chemical effect. They dissolve and carry away the rocks forming the sides of the crevices, and even eat away so much of the rock that great caves are formed. Rice's and Ball's caves south of Dubuque have long been locally famous for their extent and the beauty of the stalactites found in them. They have been described by Leonard* in some detail, but it is merely important to observe here that the formation of the crevices was due to the same agencies working in the same way as those that produced the caves everywhere common in limestone countries. In connection with the question of the origin of the ores it will be necessary to consider more in detail the character and modes of action of underground waters.

The Openings.—In sinking on one of the crevices or vertical seams it is customary to find that the vein opens out at intervals in large cavities in which the bulk of the ore is normally found. These openings occur quite constantly at certain definite stratigraphic planes listed below as ore horizons. It is not unusual, however, to find chimneys extending from one horizon nearly, if not quite to the one above. On the other hand a broad and well defined opening may be abruptly closed in by a flat "cap rock" cut by a mere line marking the course of the crevice (figure 67). Below the openings the crevices close up again, occasionally abruptly but more usually by gradual narrowing in the walls. The chimneys, some of which are illustrated in the sketches of the mines, are commonly located where the master crevice is crossed by a minor one. They seem to develop from below upward. The opening below being clear, a portion of the roof caves in. This material being dissolved and carried away, more drops, and so the process continues until the chimney has eaten its way up to some resistant

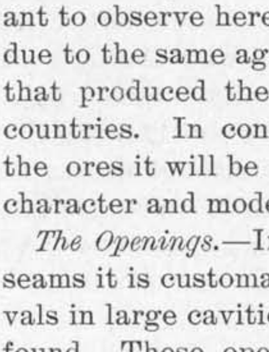


Fig. 67. An opening showing crevice cutting cap rock above and an accumulation of dolomitic sands below.

*Lead and Zinc Deposits of Iowa, Iowa Geol. Surv., Vol. VI, pp. 30-35.

stratum or to the first opening above. The chimneys, as well as the crevices, may be full, or partially full, of great blocks of fallen rock, of brecciated dolomite, or of dolomitic sands. Occasionally these sands have evidently been moved by running water and redeposited just as above ground. In the Kane Brothers mine near Key West cross-bedded sands were seen, and the upper opening, which should normally be found forty feet below the slate, had been cut up so high that the basal portion of the Maquoketa was exposed in the roof. The actual open space was here some feet above the normal level of the first "opening," and the space between was filled with soft dolomitic sands.

The reason for the expansion of the crevices at definite horizons is doubtless to be found in the greater solubility of the rock of the particular layers occurring at these horizons. Analyses made, however, with a view to determining this fail to show anything conclusive. There seems to be no greater difference for example between the character of the rock of the first opening (analysis 43) and that of the upper thin beds (analysis 41), than between other portions of the Galena. An alternative hypothesis is that the various openings indicate definite stages of level of the underground drainage much as terraces mark similar stages along surface streams. If this were true, however, it would be expected that as one passed back from the main drainage lines the openings would forsake the particular beds usually affected and rise as would the grade of a surface stream. While there are some facts which suggest such an interpretation, it cannot in fairness be said that much of the evidence supports it. The openings follow particular beds rather closely, and the movement of underground water is too capricious to be with any certainty referred to definite grade levels. Solution is so much more important than erosion that there seems to be but little opportunity for the development of an underground base level, if such a term may be used.

In any consideration of possible lower ore bodies it is important to know whether the crevices and openings may be expected to occur in the lower portion of the Galena, the part now below water level. There is no reason to doubt that the crevices extended down to the Trenton if not to the St. Peter. As already suggested the Trenton has been cut up more frequently by a number of small crevices rather than by a few big ones. Nevertheless direct observation shows that at Eagle Point and elsewhere the lower portion of the Galena and the Trenton are cut by crevices in all particulars fitted to serve as ore carriers.

The question of possible lower openings depends manifestly on the former level of drainage. Large cavities are only cut in the rock where the latter stands high enough above the surrounding drainage level to permit relatively free underground circulation. Below such a level the rocks are full of water which moves but slowly and in obedience to the principles controlling artesian wells. There is no reason to believe that such waters exert any important influence in the matter of cutting out or eating out large openings, such as are common in this region. Their action in ore deposition is rather metasomatic. As the water takes up into solution a portion of the limestone or other country rock it deposits a corresponding portion of ore. This process leads naturally to the formation of ill defined disseminated ore bodies. So far such ore bodies have not proven to be important in the Dubuque region. The ore bodies now mined are found in cavities such as could only be formed, in any notable degree at least, in rocks above the general water level. The question then becomes one as to whether the general water level ever stood lower than at present.

Chamberlin, Salisbury,* and Leverett,† who have studied this question in connection with the past history of the Mississippi, believe that the present river bed has been filled in to a notable degree; probably as much as 100 to 150

*Chamberlin and Salisbury: Sixth Ann. Rept. U. S. Geol. Surv., p. 223.
†Leverett: Jour. Geol., Vol. III, pp. 746-749.

feet. At Dubuque Leverett places bed rock at 453 feet above tide, or 132 feet below low water level. An inspection of the topographic map shows that the Couler valley and the valleys of the Little Maquoketa and Catfish creek, have obviously been filled near their mouths. At the Julien House, elevation 615 A. T., the depth to rock was shown by the artesian well to be 210 feet.*

Leverett's observations are confirmed by all that is known of the Mississippi, and while the latter may not always have been the master stream of the region, it certainly has been for a very long period. As the master stream it has determined the grade level of the tributary flows, both above and below ground. Since at one time it flowed at a level of 100 feet or so below its present surface, and apparently maintained itself at this level for a considerable period, there is little reason to doubt that the circulation of water through the lower portions of the Galena has been active enough to lead to the formation of openings, though they would naturally not be expected to be either so numerous nor so large as in the upper, more exposed, portion of the formation.

Ore horizons.—Taking up in detail the various layers which make up the Galena, there are certain ones which attract especial attention, since they are characteristic ore horizons. It is not that ore is always found at these horizons or that it is never found elsewhere, but the great bulk of the ore so far mined is found along these horizons or near them. These openings, from the top down are as follows:

1. *Top opening.*—Commonly worked in West Dubuque. May be seen in the quarries on Eighth street and is represented in figure 47. This occurs below the thin beds or quarry rock and is normally about forty feet below the base of the Maquoketa and about twenty feet above the Receptaculites horizon elsewhere noted. As is true of all of the openings, this one may chimney up a number of feet, in this case being occasionally

*Norton: Iowa Geol. Surv., Vol. VI, p. 213.

open clear to the slate. The horizon given is the one at which the opening is most commonly found.

2. *Middle or second opening.*—Occurs in heavy bedded dolomite forty-three feet below the top opening.

3. *Third opening.*—This is the lowest one worked in West Dubuque and carries jack in the Alpine, Avenue Top, Bush, Fourteenth street and other shafts of the region. It is normally twenty-six feet below the second opening, though the two may be chimneyed together.

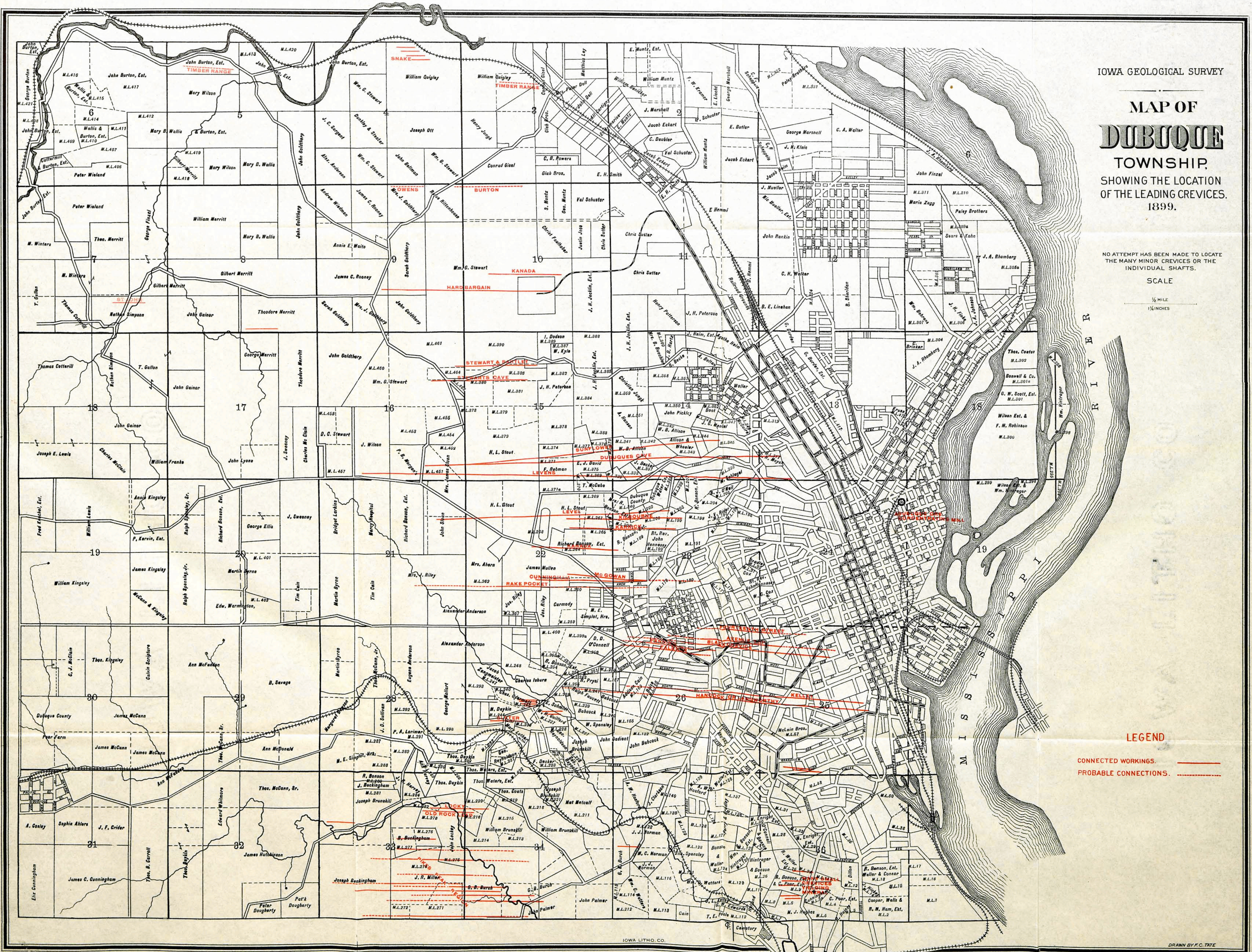
4. *Upper Flint opening or jack opening.*—Found approximately twenty feet below the cap of the third opening. Not worked in West Dubuque though known to carry ore in certain mines. Open at Durango and in the Pike's Peak region. The upper flint and the third opening often run together.

5. *Lower Flint opening.*—Separated from the upper flint opening by about twenty feet of fine dolomite. This horizon is very productive in the region adjacent to Shullsburg, Wisconsin, where it is often known as the sixty-five-foot opening, that being its approximate distance above the base of the Galena. At Eagle Point the two beds of flint are quite distinct. Elsewhere in Dubuque county they seem to merge so that it is not certain that numbers 4 and 5 will prove to be distinct horizons here.

6. *Pipe clay opening.*—At the top of the Trenton limestone at Eagle Point there is a bed of green shale which seems to mark a definite stratigraphic horizon. In Wisconsin this has proven a good ore horizon, though in Iowa there is as yet no evidence on this point, the shale never having been prospected.

It is this opening which has yielded east of the river the largest amount of ore, and which so frequently shows well developed flats. Blake speaks of it as "at the base of the ore deposits,"* and over much of the region this will doubtless be found to hold true. Ore has, however, been found below it, and Whitney speaks of the "Glass Rock" opening

* Trans. Amer. Inst. Ming. Eng., Vol. XXII, p. 63.



IOWA GEOLOGICAL SURVEY
MAP OF
DUBUQUE
TOWNSHIP,
SHOWING THE LOCATION
OF THE LEADING CREVICES.
1899.
NO ATTEMPT HAS BEEN MADE TO LOCATE THE MANY MINOR CREVICES OR THE INDIVIDUAL SHAFTS.
SCALE
LEGEND
CONNECTED WORKINGS.
PROBABLE CONNECTIONS.
MISSISSIPPI RIVER
IOWA LITHO. CO.
DRAWN BY F.C. TATE

and the "Lower Pipe clay" opening, both of which mark horizons below this. The former occurs at the juncture of the blue limestone and the lower buff beds, and the latter is at the horizon of the shales found between the lower buff beds and the Saint Peter sandstone. No great hopes that these horizons will prove widely productive can, however, be fairly held out.

DESCRIPTION OF INDIVIDUAL CREVICES.

Before taking up the question of the origin of the ores and certain practical matters connected with their mining and milling, it seems best to give brief descriptions of the leading workings. Since many individual shafts are located at different points along the same crevice, it is convenient to take up the subject by crevices or ranges, the latter term in this region being understood to cover a series of closely parallel crevices acting essentially as a unit. Many of these crevices are not now being worked, and of others it has only been possible to visit a portion of their known extent. In a few instances mines have been open during a portion of the time devoted to this survey and still it has proven impracticable to visit them. Not all of the crevices have been definitely located, and upon the accompanying map (Plate No. 7) only the leading ones are indicated. For purposes of comparison Whitney's map of 1858 is reproduced. (Plate No. 8.) Certain of the descriptions and figures of the older mines are also from this report.

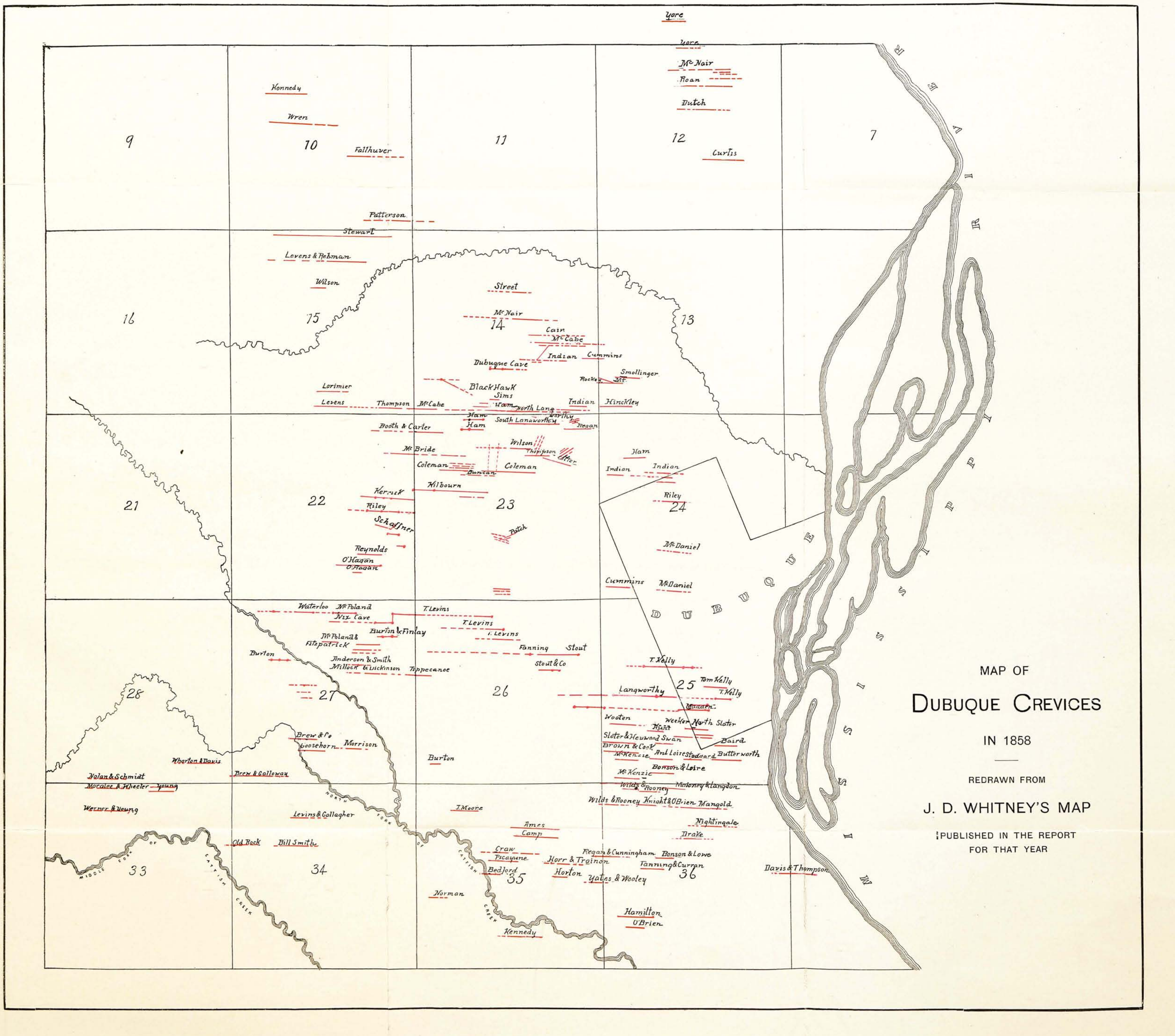
Much the larger number of the mines so far worked within Dubuque county are located within the immediate vicinity of Dubuque, and many of them are within the city limits. Some of the most important are in the thickly settled portion of the city, and are reached easily by street cars. Dubuque township includes nearly all the mining territory. A certain amount of ore was formerly found near Peru, in the township of that name, and mines have been worked in Jefferson township, around Sherrill Mound and elsewhere. Table Mound township, notably near Key West and Rockdale, has yielded some ore, and the Kane Bros. mine near Key West is now yielding lead. In Mosalem township some ore has been found, though no important mines have been opened. It is believed that all the area marked on the accompanying geological map as covered by Maquoketa and Galena, that is practically all the country between the Niagara bluffs and the river, is liable to be found ore-bearing where the local conditions are favorable. Practically the largest bodies of ore have been found in the crevices south of, and parallel to, the low anticline cut by the river at Eagle Point, and in the Timber Range which parallels this anticline to the north.

The Timber Range is one of the best known in Dubuque county. It has been worked for many years, and may be traced from its intersection with the Couler valley into the hills back of Durango. The early workings were for lead, and the most extensive mining was at the old Ewing diggings. These mines were visited by Whitney in 1856, and his description is in part given below:*

The diggings on the Little Maquoketa river, near Durango, were formerly very productive, having given employment to more than one hundred and fifty men at one time: they are now almost entirely abandoned, and in 1856, when this district was last visited by us, only a few persons were engaged in washing over the old rubbish. There is a very remarkable range or series of crevices running N. 80° W., S. 80° E. for a distance of between one and two miles along the middle fork of the Little Maquoketa: in this range, the indications of heavy workings may be seen on almost all of the points of the bluffs coming down to the river on the south side. On the Sw. ¼ Sec. 31, Tp. 90, R. II E. at Ewing's diggings, the crevice is said to have been thirty feet wide, and to have produced large quantities of lead. This locality will be noticed farther on, under the head of zinc.

Within the limits of Iowa the only ore of zinc which we have noticed in any considerable quantity, was the carbonate, associated with the silicate, at Ewing's diggings on the Little Maquoketa, a few miles northwest of Dubuque. Although the interior of the excavations was not accessible, it was evident from the inspection of the rubbish lying on the surface, that a considerable quantity of these ores, called by the miners "dry bone," had been raised in connection with the Galena. Much of the ore at this locality has a cellular structure and an earthy texture, and portions of this variety are covered with stalactitic and botryoidal incrustations. The chemical examination of some of the cellular masses showed them to consist of mixtures of the hydrous silicate of zinc, or electric calamine, with the carbonate, or smithsonite, and more or less argillaceous matter. The first mentioned of these ores contains 67.4 per cent of the oxide of zinc; the other,

*Geology of Iowa (Hall), Vol. I, pp. 457-470.


MAP OF
DUBUQUE CREVICES
IN 1858
REDRAWN FROM
J. D. WHITNEY'S MAP
PUBLISHED IN THE REPORT
FOR THAT YEAR
DUBUQUE
MISSISSIPPI RIVER
9
10
11
12
7
16
15
14
13
21
22
23
24
28
27
26
25
33
34
35
36
Kennedy
Wren
Fallhuver
Patterson
Stewart
Levens & Rebman
Wilson
Street
McNair
Cain
McCabe
Indian
Cummins
Dubuque Cave
Smollinger
Black Hawk
Sims
Lorimier
Levens
Thompson
Hinckley
Booth & Carter
McBride
Coleman
Wilbourn
Kerrick
Riley
Schaffner
Reynolds
O'Hagan
Ham
Indian
Langworthy
T. Kelly
Tom Kelly
Wooten
Burton
Morrison
Nolan & Schmidt
Brew & Galloway
Levins & Gallagher
Old Beck
Bill Smith
Norman
Kennedy
Hamilton
O'Brien
Davis & Thompson
Curtis
Dutch
Roan
Yore
Waterloo
Nix Cave
T. Levins
Fanning
Stout
Stout & Co
Tippecanoe
Anderson & Smith
Ames
Camp
Craw
Picayune
Bedford
Horr & Treinor
Horton
Yates & Wooley
Regan & Cunningham
Bonson & Lowe
Fanning & Curran
Nightingale
Drake
Mangold
Knight & O'Brien
Wilds & Rooney
Maloney & Langdon
Butterworth
Baird
NORTH FORK OF CATFISH CREEK
MIDDLE FORK OF CATFISH CREEK

64.8 of the same. Analyses of the incrustation and of the stalactitic masses proved them to consist of nearly pure carbonate of zinc, giving the following results:

	PER CENT.
Insoluble in acid, silica, chiefly	.14
Oxide of iron and alumina	2.96
Oxide of zinc (49.67 zinc)	61.89
Carbonic acid, water and loss	35.01
Total	100 00

A specimen of the stalactitic variety gave:

	PER CENT.
Insoluble silica and clay	2.56
Oxide of iron and alumina	.66
Oxide of zinc (49.38 zinc)	61.53
Carbonic acid	32 03
Water and loss	3 22
Total	100.00

In 1894-96 the Durango mines were extensively worked for dry bone by Mr. E. T. Goldthorpe. Dr. Leonard visited the works at that time and has given the following description:*

The Timber Range, or old "Ewing Diggings" at Durango, five miles northwest of Dubuque (Tp. 90 N., R. I E., Sec. 36, Se. ¼.) was once famous for its Galena. The range has a width of 100 feet and is formed by three main crevices

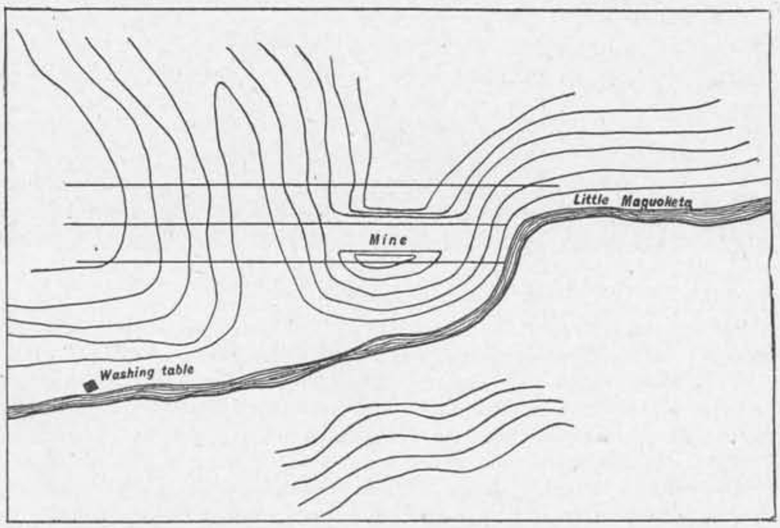


Fig. 68. Sketch showing location of Durango zinc mine in hill above the Little Maquoketa. The crevices represented.

with a general direction S. 80° E. The openings occur ninety feet below the crown of the hill, and where they are enlarged the three fissures unite in caverns of immense size.

*Iowa Geol. Surv., Vol. VI, pp. 45-47.

In these openings the lead occurred, and above them, extending to the surface, the hill is filled with zinc carbonate. The zinc is known to extend also below the level of the lead. The mine is worked by means of an open cut extending through the hill with a width of forty feet and a depth of about eighty feet. The crevices are more or less open up to the surface. Several can be seen in the face of the cut, and in them the ore is most abundant, though this is also found mixed all through the fractured limestone. The strata have been subjected to more or less strain, possibly owing to the large caves below, and are broken into fragments. The carbonate is found coating these pieces and filling the spaces between, occurring also, as stated, in the open crevices. The latter,

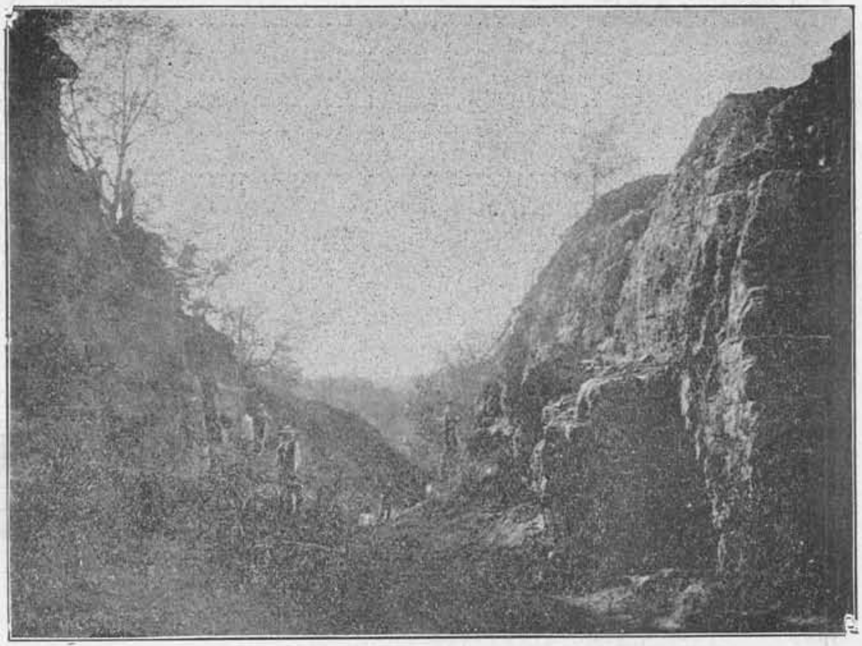


Fig. 69. Open cut at Durango zinc mine.

where they appear in the cut, have a width of from one to two feet. In working the mine the larger masses are blasted, and the smaller ones loosened with the pick. The ore is removed from the rock, the latter is carted off to the dump, and the dry bone, mixed with more or less waste material, is carried to a neighboring stream. Here it is washed by an ingenious contrivance which thoroughly frees the ore from all sand and dirt. An Archimedes screw, turned by horsepower, revolves in a trough through which a stream of water is kept flowing. As the screw revolves it gradually works the ore up the gentle incline while the water runs down and carries with it all sand and dirt. Afterwards the dry bone is picked over by hand and the rock fragments thus separated. During the past season eighteen men were employed at the mine and the daily output was from fifteen to eighteen tons of ore. This would mean a yield of over 2,500 tons for six months and is probably about the annual production of the mine for the last few years. The only zinc ore occurring in any amount at the Durango mine is the carbonate. Lead occurs in small amounts mixed with the zinc, this being one of the two instances noted in which this phenomenon appeared.

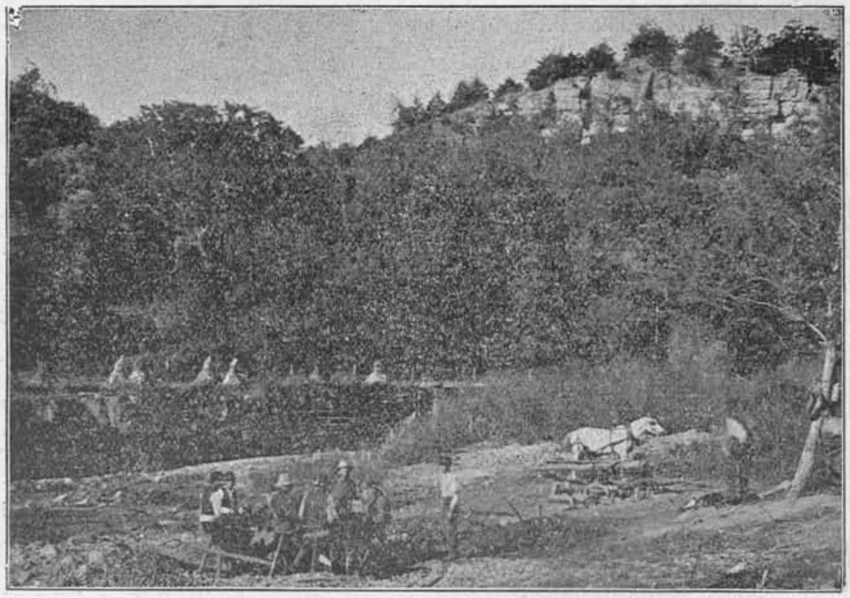


Fig. 70. Cleaning ore from the Durango zinc mine.

The Timber range yielded better in the vicinity of Durango than farther east, though some lead has been taken out at several points along it. As a whole the range has probably not been adequately prospected, and it is not improbable that it may again become an important producer. From its location well to the north, horizons lower than most of the Dubuque mines have been worked on it. At the same time it does not seem to have been worked to the base of the Galena, and lower bodies of ore may still be found in it.

In the vicinity of Durango a number of crevices have been opened up, but in general it is impracticable to correlate them with the crevices known farther east. The Snake diggings in the Ne. ¼ of Sec. 4, Dubuque Tp., may or may not represent a portion of the Timber range itself. On the accompanying map their general location only is indicated. The important crevice in which the iron ore at Durango is found is not correlated to the east. The level in this crevice is opened along the upper limit of the flint beds, and certain test pits sunk along it show mineral at about the proper distance below the lower flint opening, which would indicate that in Iowa, as in Wisconsin, these horizons may be expected to be valuable.

Stewart's Park ranges.—South from the Timber range there is a considerable strip of barren country probably marking the crest of the Eagle Point anticline, though it is difficult to locate the anticline accurately under the upland. Apparently the course is from Eagle Point to Derby Grange (Se. ¼ Sec. 8). The Owens and Burton ranges would accordingly lie north of this anticline, while the Hard Bargain, Kanada or Kennedy, and other Park ranges would be immediately south of it.

The Owens was first struck in the winter of 1859-60 and in that and the following year is said to have yielded 2,000,000 pounds of mineral. The Burton was worked from 1865-68, and yielded about twice as much as the Owen. The Kanada gave about the same total as the Owen, and was worked in 1857-58. None of these crevices have yielded much east or west of this land and they all made mineral at intersections with north-souths. The Owens runs west and splits up into a lot of minor crevices. Beyond this point the main crevice has not been located. The Owen lead is described and figured in the *Dubuque Herald* of June 20, 1860. The figure given there has been redrawn and is reproduced.

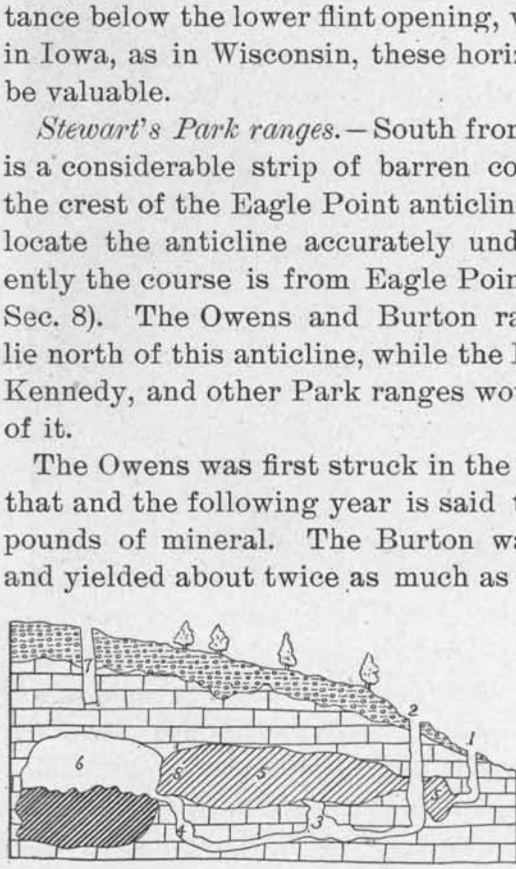


Fig. 71. The Owen's lead. Redrawn from the Dubuque Herald, June 20, 1860.

In this figure No. 1 is the first shaft from which a drift was driven west to mineral at 5. No. 2 is a second shaft, 36 feet to mineral and 72 feet deeper to a second opening, with a drift west 90 feet to a chimney, No. 3, with mineral in the top. The drift was carried on west 83 feet, where an uprise of 20 feet showed mineral again. Immediately under No. 8, a solid piece, estimated to weigh 40,000 pounds, was found. Under this was a narrow passage to a cave, No. 6, 12x30 feet and 24 feet high, filled up even with the entrance with rock and mineral. A new shaft, No. 7, was then being driven to reach this cave. At that time 200,000 pounds had been raised, 60,000 pounds in one week. On July 4th the *Herald* states that by crawling through a narrow crevice the ground had been explored some 250 feet farther west and another cave, or opening, found "loaded from floor to roof" with Galena. On July 25th the shaft No. 7 had reached the first cave, and in twenty-four hours 20,000 pounds of mineral had been raised. In all, 80,000 pounds had been raised the preceding week. On August 8th it was reported that the lead continued to yield 8,000 to 12,000 pounds per day.

The Collins crevice was worked west of the Owens and on nearly the same range. At one time, for a short period, it yielded 1,000 pounds of mineral per day. The main crevice in the district is, however, the Hard Bargain, which, starting from near the end of the present street car track, has been traced west a mile and a half to the land of James Rooney in Sw. ¼ Sec. 9. This crevice yielded a large amount of lead, and in 1834 supported a furnace, located about where the present park is now. This crevice is sometimes known as the "Old Million Lead," referring to the number of pounds of Galena taken from it.

Near the Hard Bargain is the Kanada, or Kennedy, as Whitney spells it. He gives the following description of the work at the time of his visit:*

This mine was producing largely in October, 1856. At that time the drift had been extended in the crevice to a distance of 330 feet from the shaft, which was 100 feet deep. The opening was about thirty-five feet in height, and the crevice extended upward in the cap rock, sometimes to a distance of fifteen feet or more. The Galena was said by the miners to have formed, for some distance, a solid sheet three and a half feet thick; in some places the rock was undecomposed; in

*Geol. Iowa (Hall), Vol. I, p. 454.

others, the crevice was filled with tumbling rock mixed with Galena. Over 1,000,000 pounds of ore had been taken from this rich deposit in the six months preceding our visit.

The Stewart Park ranges are not known to the west, though some mineral has been mined in section 7 on what was then

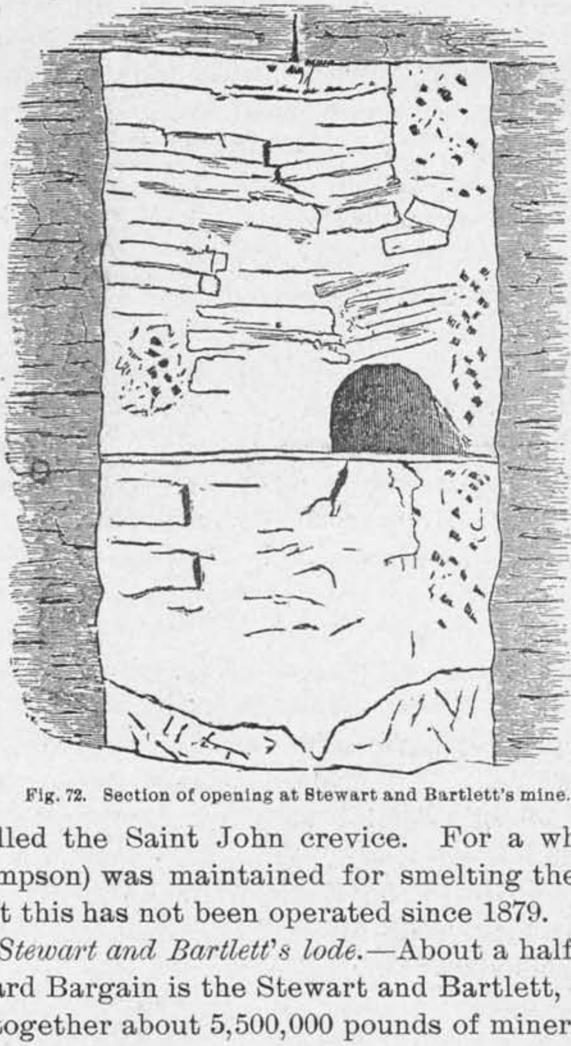


Fig. 72. Section of opening at Stewart and Bartlett's mine. (Whitney, figure 48.)

called the Saint John crevice. For a while a furnace (the Simpson) was maintained for smelting the lead found here, but this has not been operated since 1879.

Stewart and Bartlett's lode.—About a half mile south of the Hard Bargain is the Stewart and Bartlett, which has yielded altogether about 5,500,000 pounds of mineral. It is not now open. Whitney's description and figures are given below:*

This very interesting locality was still partially open for examination in 1854 and 5, although most of the lead had been taken out. Some of the appearances

*Geol. Iowa (Hall), Vol. I, p. 418.

observed here are peculiar, and throw some light on the mode of deposition of the ore, as well as on the action by which the crevices have been formed.

A space was worked out, open to-day, at one end of which a good exhibition was afforded of the mode of occurrence of the ore at this locality, and of the manner in which the strata had been impregnated with it, through the limited space called the opening; the rock remaining, in this part of the mine, nearly in its original position, not having been washed away. The wood cut, figure 48,[Fig. 72 of this report], represents the general appearance of the rock at this point. The width of theopening, between the walls, is about fifteen feet, and its vertical height not far from thirty-five feet. Within this space, it will be seen, that the strata are slightly bent downwards and broken in numerous places, leaving cavities between the fractured edges of the strata in which a portion of the ore has been deposited, as represented by the patches of oblique shading. The larger part of it, however, is collected along the walls of the opening, especially on the north side, where the rock is broken up into small pieces and somewhat decomposed, forming with the ore a brecciated ferruginous mass. The decomposition of the rock had evidently not proceeded quite as far in this case as in some others, or we should have had, instead of the mass of fractured strata still in place, a cave limited by the walls of the opening on each side and filled partially with detritus, clay and "tumbling rock," with fragments of galena scattered through it.

The workings at this locality have been on two different levels, in an irregular crevice, or two crevices connected together by flat openings. The excavations on the upper level follow an irregular crevice for several hundred feet, which had been entirely worked out before being examined by us, and which is said to have produced but little mineral. The lower drift is forty-two feet below the level of the upper, and was extended a little over 270 feet to the west of the shaft, and a considerable distance in the other direction, but how far, was not ascertained, as it had become filled up in that direction; probably over 800 feet. This lower drift runs in a crevice of varying width and height, sometimes widening out to twelve or fifteen feet, in other places closing within a few inches, and chiefly filled with clay and decomposed rock with fragments of ore. At the extremity of this drift the crevice comes to an abrupt termination, in a cavity such as would have been produced by the sinking down of a portion of the rock shaped something like a flat-bottomed boat, as represented in the annexed wood-cut, figure in 49, which the part left white indicates the vacant space, the flat upper part of which is fourteen feet wide and two and a half feet high, while the crevice runs off on each side at a steep angle, to an unknown depth. At the upper right hand corner, the crevice is seen continued upwards in the cap-rock: this probably connects with the crevice worked in the upper drift, as

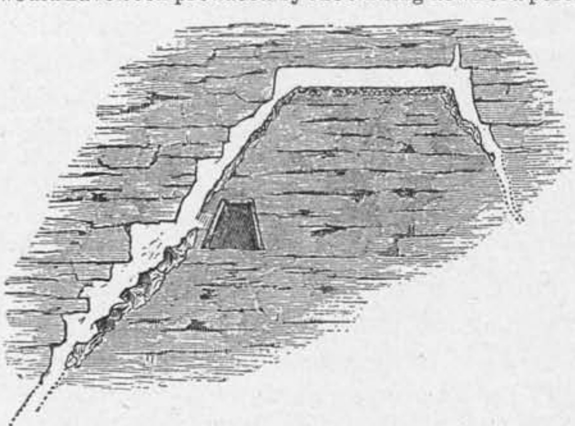


Fig. 73. Section at west end of Stewart and Bartlett's lead. (Whitney, figure 49.)

noticed before, and which was somewhat to the north of the lower one. The section is an interesting one, as showing how the formation of the crevice, in this portion of it at least, was due to a mechanical cause originating within and confined to a limited space in the rock.

We were informed that four millions of pounds of mineral had been taken from these excavations, which, when visited by us last year, seemed to have been entirely abandoned, and were rapidly filling up again with clay and sand.

Near this lead are the Ruly and the Timmons, both important producers, not now open.

Stewart's cave.—This cave is located at the intersection of a bunch of crevices, as indicated upon the accompanying sketch map (figure 74). It is reached by means of a shaft upon

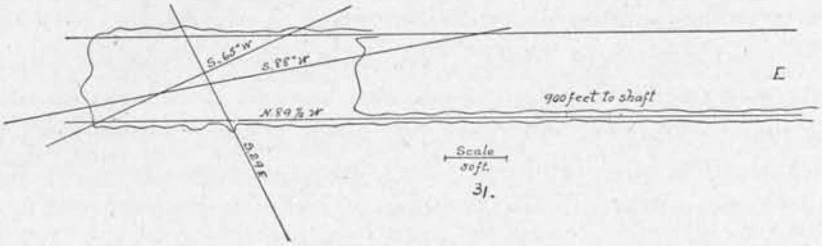


Fig. 74. Sketch map showing crevices which form the Stewart's cave.

an east-west crevice, whose south wall forms the south wall of the cave proper. The crevice itself is now open for 900 feet from the shaft to the cave. It shows along this distance a well marked crevice in the roof and is opened out to a width of from fourteen inches to three feet. Along much of the distance it is stoped out to a height of twenty-five to fifty feet. Drop shafts along its course go down forty feet in soft dolomitic sand without any sign of bottom, but show mineral at that depth near the water level. This mineral is in large cubes, "cog mineral," and is more abundant near the cave than farther east. The rust or ocher is more prominent near the shaft. The sands in the bottom of the crevice show cross-bedding and indicate actual movement of material along the crevice. The recent prospecting seems to have developed ore mainly at crevice intersections. The crevice forming the north side of the cave is, so far as known, barren.

The walls of the main crevice are weathered, as on an exposed cliff face, that is, so as to bring out very sharply the bedding planes. These correspond from side to side and there is no indication whatever of any faulting, either vertical or horizontal. The main crevice is cut by occasional cross-crevices both north-south, northeast-southwest and northwest-southeast. Occasionally two of these cross in the main crevice. These cross crevices are usually marked by vertical cracks in the wall rock, as much as three inches across and filled with dolomitic sand.

The cave itself is an irregular rectangle about 80x200 feet, and if it were cleared of fallen rock, it would be between forty and fifty feet high. The fallen rock, however, fills it nearly to the roof, which is flat and unbroken; along this roof the great east-west crevices are quite plainly marked. The north-souths are feebler. The bearings as given in the sketch were taken in the summer of 1899 and are magnetic.

The bottom of the cave cannot be reached, as water stands in it. The crevice and the cave proper are, however, quite dry. There is no drip, and no spar is seen in the roof and walls. The cave was discovered through a chimney on the main east-west marked on the sketch, and considerable Galena was taken from the crevice though not from the cave. The Galena occurred in bunches high in the top of the crevice and in loose fallen masses in the sand. No systematic work has been done here for some years, though a little prospecting has been carried on. This cave is sometimes known as the Redman cave, and another range, about 1,200 feet south and developed west of it, is known as the Redman range. About a quarter of a mile still farther south are the Moses, Leathers and still other ranges.

Levens.—This is one of the most important leads in the Dubuque region and is often known as the North Langworthy. It has been worked at intervals for nearly three miles. The eastern portion, lying within the city limits, was developed by James Langworthy and Brothers between the years 1830 and 1850. The South Langworthy lies about 300 feet south of it and is not to be confused with the Langworthy or Hancock range near Mercy Hospital. Henry Stout worked the Levens farther west in 1852-53, and still farther west, on Mineral lot 371, Tom Levens, in 1855, made one of the big strikes of the region in a cave. It is estimated that he raised about 5,000,000 pounds of Galena from this lot. Some black jack was also discovered, but being at that time valueless, no attention was paid to it. After Levens abandoned the property Peter Lormier, Anderson, Walsh & Co., and others took out a little mineral, and from time to time since a small amount of work has been done on it. It is estimated that in all perhaps 15,000,000 pounds of Galena have been taken from this crevice.

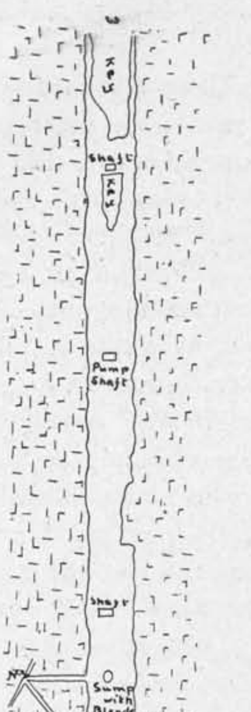
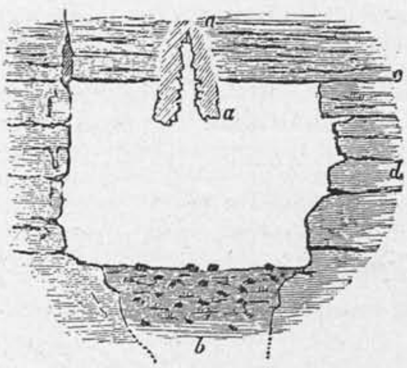


Fig. 75. Levens' cave as developed on Mineral lot 271.

Its general course is S. 83½° W. (Guilford) and it is said to vary but little from this course. The only portion of the work now open is the old Levens cave, which was visited in 1899 and again in 1900. This cave is on the Sw. ¼ of the Se. qr. of Sec. 15 (Tp. 89 N., R. II, E.). The discovery is said to have been made by crawling into the cave from the east, but later three shafts were sunk upon the cave. The middle shaft is the one from which the main mineral was hoisted. About fifty yards east of it is a shaft sunk in 1860 by Anderson & Co., and used later for a pump shaft, a forty-horse-power engine and pump being used. The work was, however, never carried much, if any, below the levels now free from water. At the intersection of the north-south, west of this, a prospect shaft showed good jack at a depth of about forty feet. Not far beyond, the crevice narrows from forty feet to two feet and less for some distance. The main portion of the cave is twenty-five to thirty-five feet wide, and thirty to forty feet high. Except for the key rock west of the pump shaft it is all open for nearly 500 feet. There are two well marked crevices and the cave has been formed by the cutting away of the rock between them. On the Stout land, half to three-quarters of a mile west of here, the crevice opens out again into a great cave from which mineral has been taken.

Figure 75 is a rough sketch of the cave as developed on Mineral ot 1271. In connection with it the following description of the cave when first found may be read with interest.*

For a description of this very interesting locality, as it appeared when first discovered, we are indebted to C. Whittlesey, who visited it immediately after its discovery by Mr. Levens, and before it had been at all disturbed. This was in October 1850; it was first visited by one of us two years later, after about two million pounds of ore had been removed from it. The locality, as at first seen by Mr. Whittlesey, presented a narrow cave or crevice entering from the side of the hill, and capable of admitting, although in some places with great difficulty, the passage of a man: the crevice had a nearly east and west direction in general, with many small deflections from a straight course. We annex Mr. Whittlesey's description of his visit to the locality in question. After speaking of the difficulty of squeezing between the walls of the narrow and winding crevice, he goes on as follows: "We had not gone far in this uncomfortable manner, when a handsome cave appeared before us, illuminated by the lights in front. It was a square room, with a mud floor and a rock ceiling, along the middle of which was a seam, or vertical crevice, containing galena. This crevice was about two feet broad, the sides covered with mineral six to eight inches thick, leaving a space between the inner faces of the mineral, up which we could see several feet. There was about this crevice an entirely new feature, so far as I know. The solid mineral projected from this crevice downward, a foot to a foot and a half in a 'sheet' as they call it, eight to ten inches thick, and twenty-five to thirty feet long, spreading fan-like as it descended. (The annexed wood-cut, figure 50, will convey an idea of this peculiar and interesting feature:



a. Depending mass of galena.
b. Detritus and clay with galena.
c. Cap rock.
d. Galena limestone.

Fig. 76. Section of Levens' cave. (Whitney, figure 50.)

*Whitney, Geol. of Iowa (Hall), Vol. I, p. 450.

it represents a section across the cave at the point where the depending sheet of ore was obserʌed, as described above.) A part of the way there were three sheets, two thick and heavy ones, with coarse irregular surfaces, composed of aggregated tubes from two to ten inches on a side, and one thin light sheet, the whole covered with oxide (carbonate?) of lead, and having, in consequence, a pure white color. This depending mass was wholly clear, except where it was attached to the rock above and projected downwards in space, the most rich and beautiful object I ever saw of a mineral kind. About two hundred feet more of twisting and squirming brought us to the leaden temple, where lay the fortune of our bold explorer. It is a cave, or pocket, some hundred and thirty feet long, twenty feet high in the dome, or cavern part and twenty to thirty feet wide, the sides and roof arched in an irregular manner. Probably it extends in this oval shape to a depth equal to the clear space above. The whole appears to have been ceiled with lead; and although its size is not as great as that of many (?) other mineral caves, the amount of galena in view at any one time is said to exceed that of any 'pocket' yet opened. Much of the lead lining the roof and sides had fallen down in immense blocks, some of them very recently. This mineral incrustation was, in places, two feet thick, and one of the fallen masses was estimated to weigh 23,000 pounds. In the mud and clay that formed the bottom, or floor, of this spacious room, they said that mineral would be found buried, or enclosed, in large lumps to the bottom, probably fifteen feet deeper."

Such was the appearance of things at this most interesting locality, certainly one of the most remarkable ever discovered, in 1850. In October, 1852, about 2,000,000 pounds of ore, worth, at the then current price of lead, about $50,000, had been removed, and there was still left in the mines about 1,500,000 pounds of ore, which was taken out in 1853 and 1854. A shaft had been sunk from the surface to strike the rich cave spoken of above, the top of which was reached at the depth of about ninety feet, and the bottom of the excavation was about forty-five feet deeper. The length to which the crevice had been traced was about 1,200 feet; and the cave-like expansion extended for nearly 300 feet, widening out in some places to twenty-five feet. The galena at this time could be seen, in some places, occupying a fissure extending upwards into the cap-rock: it also formed flat sheets running into the sides of the opening, in some places, with a thickness of three or four inches of solid ore; but by far the larger portion lay in loose masses in the bottom of the elliptical cave-like opening, mixed with clay, sand and loose masses of partially disintegrated limestone, called "tumbling rock." Besides the shell-like deposit of ore which lined the walls of this cave, as described by Mr. Whittlesey, there seem to have been horizontal layers which once extended through the opening; these had been broken up, and the rock surrounding them removed by the action of currents of water, of which the evidence could be seen in every part of the crevice, especially in the water worn and grooved lower surface of the caprock, and in the rounded edges and angles of the projectin gstrata of the sides of the opening.

The Levens has been frequently described and referred to elsewhere. In the files of the local newspapers for the years between 1850 and 1860 there are many notes on it. The *Miners' Daily Express* of November 6, 1861, gives quite a full description of it. At that time the cave had yielded about 1,000,000 pounds of mineral, and it was estimated that it would yield twice as much more. Altogether it has probably yielded between 10,000,000 and 15,000,000 pounds.

The workings are now being reopened by Bausche, Hosford & Co., who now (1900) have shafts open on both the Mettle ground (Mineral lot 371) and the Stout farm farther west. Their development work indicates that the zinc blende, discovered years ago, is developed at a number of places along the crevice in an opening approximately forty feet below the old workings. This opening bids fair to rival the upper opening in size. In order to work it, pumps will be necessary, and they with other machinery are now being installed.

Dubuque's cave.—Not far north of the Levens is a crevice supposed to have been discovered and worked by Julien Dubuque and hence called Dubuque's cave. This crevice has a general course of S. 82° W. (Magnetic, Guilford). It has been worked at many points; and in Mineral lot 452, where it intersects with the Sunflower, the first main crevice to the north, it produced nearly 500,000 pounds of Galena. On the eastern part of Mineral lot 376, it is said that some 300 tons of dry bone have been taken from it. Whitney estimates that, up to the time of his visit, the crevice had yielded 2,000,000 pounds of mineral.

In the winter of 1898–99, Mr. W. H. Guilford sunk a shaft upon this crevice east of the Mettle land, hoping to hit a quartering traced some distance from a shaft located to the northeast. The relative locations are indicated in the accompanying sketch (figure 77). The shaft was driven to a depth of ninety-eight feet, and at first, beneath the slate, showed dolomite with small flakes of disseminated lead and occasional bits of blende. Barytes, pyrite and calcite also occurred. The rock showed

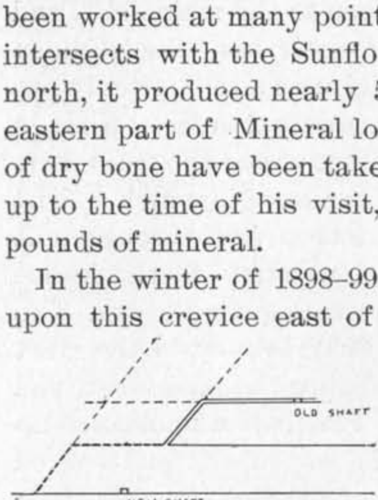


Fig 77. Guilford's prospect on the Dubuque's cave crevice.

a weak cleavage or rift in an east-west direction corresponding to the usual crevice. This continued to a depth of sixty-eight feet at which the usual first opening should have been found, but it gradually disappeared below, the rock becoming a hard blue dolomite with no signs of rift. Apparently the mineral vein traced towards this intersection had followed west on an intervening crevice to the next crossing, in this case, 150 feet beyond.

The Sunflower is an important crevice running at a considerable angle with the others in the region. (S. 79° 45′ W. Magnetic, Guilford.) At the east line of section 15 it is about 800 feet north of Levens. On Mineral lot 371 the Mettle Bros., in February of 1899, cleaned up an old shaft dug by Mr. W. H. Guilford about forty years earlier on the Sunflower, for mineral. It produced a little near the bottom of the shaft, but nothing of any great value. Dry bone was discovered at that time, but there was then no sale for it. The general situation is indicated in the accompanying sketch. (Figure 78.) The shaft is sixty-five feet deep to the main drift, and penetrates the Galena limestone twenty to twenty-five feet. Sixteen feet above the main drift is a cave in which a drift was carried through soft mud forty feet, without striking a wall rock. The shaft is now twelve feet below the main drift, and twenty-eight feet below this cave. The drift was cleaned up some 250 feet to the east, most of the way in soft mud washed in from the surface. At a distance of 200 feet from the shaft the dry bone set in, a smaller body showing at 100 feet. The bone continues to the end of the drift, and is ten to twelve feet in thickness. The width of the body is about twelve feet. At the face there is a narrow opening, and the roof is

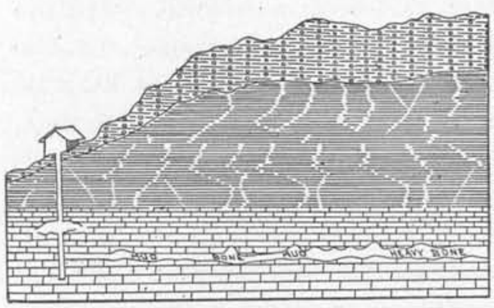


Fig. 78. Dry bone mine on Mettle land.

well defined, showing a dolomitic rock impregnated with dry bone. About 500 feet ahead of the face, and fifteen feet north, is another shaft with a level running west beyond this face. A short cross cut would cover the two workings.

Patch diggings.—There are a series of northeast-southwest quarterings lying between the Levens, or north Langworthy, and the level near their eastern limits.

Level.—This is one of the most important crevices in the Dubuque region. Its course is S. 81½° W. (Magnetic, Guilford). It has been worked for about one mile, and lies one-fourth of a mile south of the Levens. It is said to have yielded 10,000,000 pounds of ore. This crevice was opened up by level workings which were later on used as a source of water supply for the city. They are still connected with the city system, though now they do not alone furnish enough water to supply the demand. The level crevice is not supposed to be in itself so rich, but running southwest at a greater angle than is common, it picks up a number of minor crevices, each of which made a little bunch of mineral at the intersection. The level itself has not been found in the Patch diggings, though the quarterings are said to have been found richer about where its intersection should be, and on Seminary hill little crevices carrying mineral, mark its position.

It was upon the western end of the old level that the old shot tower shaft was located, and the only recent attempt at pumping for lead was made. This work was done by Capt. A. W. Hosford and E. T. Goldthorp in 1895. Mr. Leonard visited the mine and his description is given below:*

DUBUQUE LEAD MINING COMPANY.

The mine of this company is located one mile west of Dubuque and has been worked for about one year and a half. It is on the west end of the old Level Range, which has been followed for nearly three miles and has yielded considerable ore from various points along its length. At present (November, 1895) there are seventy-five men employed at the mine. The three shafts are 2:0 feet deep, with a steam hoist on one, and gins on the other two. The company have just erected a concentrator at the mine for the purpose of crushing and cleaning the ore. This was made necessary by the fact that in this mine much of the Galena occurs scattered through the rock, sometimes in particles of considerable size.

* Iowa Geol. Surv., Vol. VI, p. 48.

The limestone is crushed and the lead then separated from it. The ore-bearing dolomite forms a zone from two to four feet wide and containing an abundance of iron pyrites. This latter mineral is often found here crystallized in beautiful octahedrons with a length of from one-fourth to three-fourths inch. Besides being disseminated through the rock the Galena occurs in large masses in what is probably the fourth opening, and it likewise fills the crevice above for some distance. The ore body is apparently an extensive one; 700,000 pounds of lead have already been raised. Work in this mine is made possible only by the constant operation of a steam pump which keeps the water below the opening where the ore occurs, and thus allows the miners to reach the deposit.

A large amount of mineral was raised, a small mill was erected, and the ore was concentrated and smelted locally. The heavy expense incurred in pumping, together with the low price of lead then prevailing, caused the abandonment of the work when excellent ore was still in sight, going down into the water.

Kilbourne and Karrick.—These are two important crevices, neither of which is now being worked, lying about 300 feet apart, with the Karrick approximately one-quarter of a mile

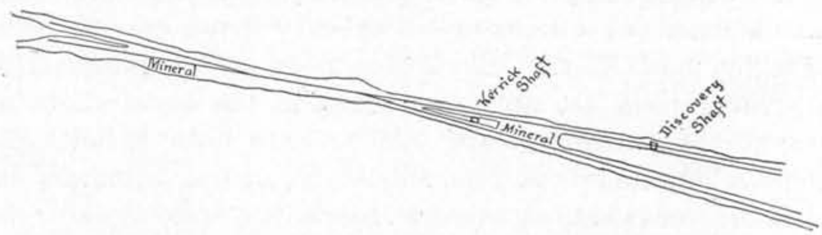


Fig. 79. Sketch of Karrick where the main body of lead was found.

south of the Level. The course of the Karrick is S. 89° 30′ W. (Guilford, Magnetic). It is cut by numerous northeast-southwest quarterings which seem to have led the mineral, originally worked in the Kilbourne, across into the Karrick. Some of the cross crevices come in at a very low angle. One, at what was known as the Polly shaft, coming in at N. 86° W., crosses the main crevice, making at the intersection a room thirty feet wide. The Karrick shaft proper was sunk on a key rock (figure 79), but was near a big body of mineral running for about 400 feet east and west. The Kilbourne is estimated to have yielded about 2,000,000 and the Karrick 10,000,000 pounds of mineral.

The Karrick was owned at the period of its heaviest development by the late Gen. George W. Jones, and his son, Mr. G. R. G. Jones kindly supplied the following note on the mine:

The mine was discovered by Capt. George Ord Karrick a little over forty years ago. Captain Karrick began prospecting on the old Kilbourne range, which is about 100 yards north of the Karrick. The Kilbourne was discovered by two English miners, and their prospect looked so well that my father, Gen. George W. Jones, bought it, paying $10,000 cash in gold for it. The Kilbourne proved to be a very rich lode. It contained solid bodies of ore as large as a bureau. After Captain Karrick had worked a while on the Kilbourne, which seemed to have given out in production of mineral, he came to the conclusion that the lead had gone somewhere else, and said that it had "jumped down" to the south. He then began prospecting on the present Karrick range, and soon struck ore which he followed west until the crevice opened out into very large dimensions, with numerous chimneys and caves. Four shafts were sunk on the Karrick, the "pump" shaft being the largest shaft in the Dubuque mines, five by ten feet. The water in the mines was very great in volume at that time. Now there is scarcely any water in the Karrick crevice. Captain Karrick began on the water with a chain pump worked by hand; then put on a gin with oxen for motive power and whiskey barrels for buckets. Horses were afterwards tried, and then a large steam pump, twelve inches, was erected. This pump was worked with a walking beam and large fly wheel. A battery of five steamboat boilers supplied the steam, and, as in those days coal was only to be had at Pittsburg, Penn., cord wood was used for the boilers. This fuel cost the company $100 per day and kept ten wagons hauling wood. When this pump was operating, water in mines one or two miles from the Karrick was lowered, and many wells and springs for miles around went dry, thus showing the Karrick to be a great central crevice. As many as 300 men were employed at one time on the Karrick mine. During the working of this mine the price of ore varied, but some thousands were sold from the Karrick for as high as $125 per 1,000 pounds. The Karrick has earned more than $800,000, all coming out of first opening. This mine has never been worked at a depth lower than 125 feet, and two or three openings have never been reached. It was the opinion of the U. S. mining engineers, who examined this mine over thirty years ago, that biggest mineral would be found still lower down. Deep mining has never been tried to any extent at Dubuque mines.

The mine was open at the time Whitney was in the region, and his notes on it are given below:*

Kerrick and Jones lode.—This is one of the most important and interesting deposits of lead which has been worked in recent years. The crevice is remarkable for its length and regularity as well as for its productiveness, it having already yielded over a million and a half of ore. It has almost exactly an east and west direction, the magnetic bearing between the shafts, proceeding in a westerly direction, being from No. 1 to No. 2, S. 85° W.; No. 2 to No. 3, S. 83° W.; No. 3 to No. 4, S. 83½° W. (the magnetic variation is about 8 E.). It has been opened for a length of nearly fifteen hundred feet, having a width from six to eight feet, except where divided into two portions by the "key-rock," when it widens out to twelve or fifteen.

*Whitney: Op. cit. p. 453.

At the time this locality was visited by us, in October 1857, the end of the drift going west was distant about three hundred feet from the engine shaft, and the crevice presented the appearance represented by the annexed section (figure 51), its width at this point being about six and its height about eight feet. The opening was filled with soft clay; the ore occupying a fissure extending upwards in the top of the drift, and having a width of nineteen inches (represented at *a* in the figure), all of which was solid galena, with the exception of a narrow, irregular space in the center, the ore having crystallized on both sides of the fissure, but not filling it up entirely. Twenty feet before reaching this point a solid sheet of mineral had been struck, which extended from the floor to the top of the crevice. Between this point and the shaft the crevice appears to have quite a variable height, the excavation having a height of forty or fifty feet, the crevice having extended upwards in the cap-rock and carried ore for a considerable distance. A section of the crevice at another point is represented in the annexed wood cut (figure 52), which shows the position of the so-called "key rock," an irregular mass of limestone remaining undecomposed along the center of the crevice, which divides it into two parts, as is frequently the case in the wide vertical openings: this disposition resembles the splitting of veins, so as to include large masses of rock, called, by the Cornish miners, "horses," and which are common in other mining regions.

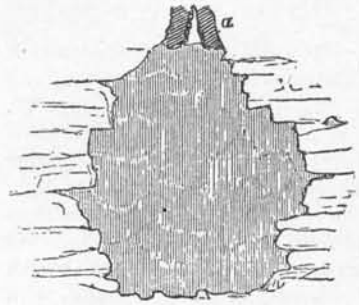


Fig. 80 Section at Karrick and Jones lode. (Whitney, figure 51.)

The workings on the crevice have been several times suspended and resumed, on account of the abundance of water, the shaft having reached a depth of 110 feet. After several abortive attempts to introduce new-fangled and ill-contrived machinery for pumping, a steam engine was erected which operated a suitable pump with twenty-one inch lifts, raising 700 gallons per minute and with the aid of which it was intended to sinkthe shaft twelve feet deeper.

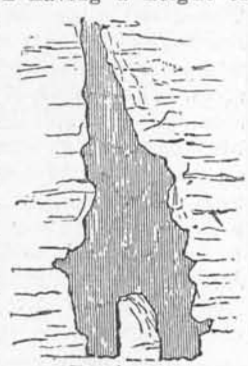


Fig. 81. Section showing key rock in the Karrick. (Whitney, figure 52.)

This was the only locality, at this time, where steam power was in use on this side of the river for draining a mine. Another engine was erected at Riley's lode, a few rods south of this, and which has been worked for some years, over an extent of several hundred feet longitudinally and to a depth of 137 feet, and much mineral raised; 2,000,000, it is said. The crevice, which was not accessible, was found to be almost exactly parallel with that of Kerrick & Jones, its mean direction being N. 86° E., S. 86° W., magnetic.

The *Dubuque Herald* of June 20, 1860, speaks of the work having ceased, pending some new financial arrangement, and deplores the heavy investment in pumps therefore standing idle. The mine has not been worked for some years but a shaft on the Kerrick is now open on the Ahern ground and a good grade of zinc blende is shown at the bottom.

McGowen and Cunningham crevices.—These are two important and interesting crevices running through sections 22 and 23. The course of the former is N. 72° 30′ W., and the latter N 85° W. (Magnetic, Guilford.) They intersect in Mineral lot 179, and east of that the McGowen is not known, though the Cunningham is worked some distance under the city. Messrs James Hird & Son have, for some years, worked this crevice for dry bone. Mr. Leonard's description of their workings is as follows:*

THE M'GOWEN CREVICE.

Direction N. 86° W. This crevice is located just west of Dubuque and was formerly operated for lead, but for the past eight years it has produced zinc ore. The shaft is 112 feet deep. Only the first of the openings present has been explored. The greater portion is above the cap rock and is called by the miners a "cap rock" opening. The expanded crevice is a large one, the average height being forty to fifty feet, and the width four to ten feet. In some portions it opens into caves with twice the above width, and these are filled with zinc ore mixed with clay and more or less rock, much as in the Durango mine. Some twelve feet west of the shaft the lead gave out and a few yards beyond zinc carbonate began to appear and soon occupied the entire opening. At one point almost the whole cavity is filled by the "keyrock," leaving only a narrow space on either side for the ore."

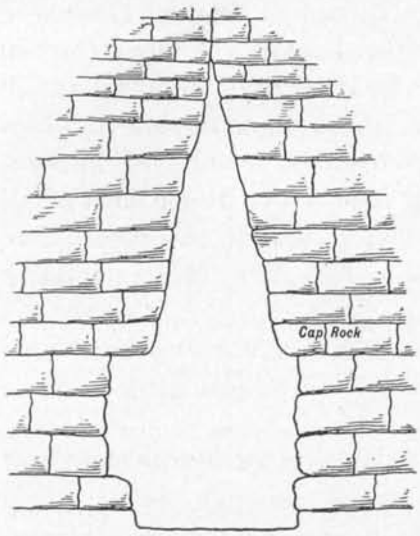


Fig. 82. McGowen crevice showing cap rock opening.

Rake Pocket.—This is an important crevice a short distance south of the Cunningham. Its course is given at S. 86° 15′ W. It has been worked on the Ahern ground, Mineral lot 262, and east under the city, but the intermediate ground and the territory to the west have not been opened up. On the Ahern ground

* Leonard: Op. cit. p. 48.

is the Halpin mine, which yielded 967,265 pounds of galena in 1898, besides a considerable amount in 1897.

The situation at this mine is illustrated in the accompanying sketch (figure 83). The shaft is 116 feet deep, and to the east the ore has been stoped out for a height of about sixty feet, and twelve feet wide, for a distance of approximately 100 feet. The ore occurred as large lumps of Galena mixed with sand and a little fallen rock. West of the shaft, for perhaps 100 feet, the opening is about six to eight feet high and eight feet wide; it carried ore in loose dolomitic sand. Beyond this there is a twenty-foot up-rise to a narrow drift driven along the cap for 300 feet. Drop shafts from this drift show mineral at the water level, which is about the same as at the shaft. In a small cave near the cap some 4,000 pounds of mineral were found in one bunch. Near this cave there is a small opening along a north-south crevice which intersects five parallel east-west crevices; these last are only partially explored.

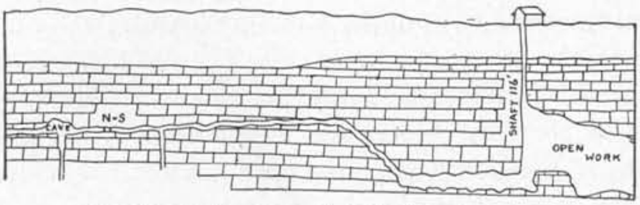


FIG. 83. Halpin mine on Rake Pocket crevice,

An attempt to handle the water here by barrel proved useless, and it will be necessary to put on pumps if the work is to be carried any deeper.

Julien Avenue crevices.—About a quarter of a mile south of the Rake Pocket, and near Julien avenue, is a group of important crevices of which the Fourteenth street, the Avenue Top or McNulty, the Black, Falkner, and Fanning are best known. These have all been worked for some years and the first three named are now supporting important mines.

In figure 84 the workings of the Fourteenth street mine are represented. The general course of the crevice is S. 85° W. (Magnetic). The shaft is 150 feet deep and stops at water level in the lower opening. It is nineteen feet from the top of the upper opening to the bottom of the lower. The mine has been worked mainly for dry bone and has produced as much as a carload a day. On the upper level the opening has been followed west several hundred feet, and a big chimney was found

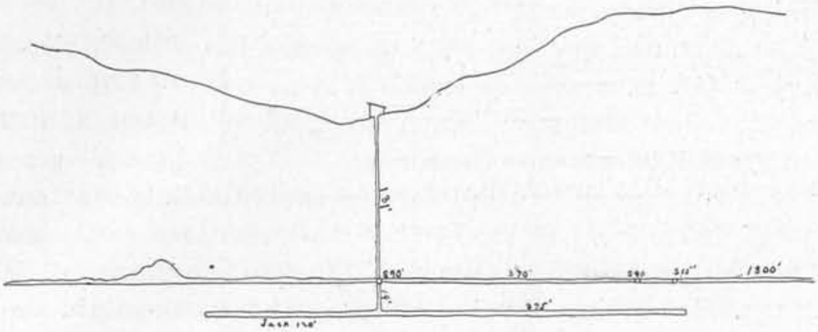


Fig. 84. Fourteenth Street mine.

as indicated in the sketch. From the shaft a drift was run south ninety feet and yielded good dry bone all the way. East of this level, at a distance of 370 feet, a level has been run south thirty-five feet, and twenty feet beyond it a second has been carried south fifteen feet. Beyond this the crevice has been followed 1,300 feet. These various entries at this level all yielded good dry bone and show much mill dirt yet in the walls. They average about four by six in cross section, and the wall rock is said to run 18 to 20 per cent of dry bone.

The second level has been driven approximately 160 feet west, with a cross section 4x4, and 375 feet east. Dry bone was taken out in driving each entry, and for a distance of 120 feet along the west entry an excellent grade of blende shows in the walls and bottoms. Messrs. Mays & Co. have recently taken hold of this property, erected a steam hoist, and are now sinking and driving east. A face, 6x8 feet in cross section, is carried to the east, showing a mixed jack and dry bone ore. Recently a very fine body of dry bone has been found. Deep drop shafts, driven from the upper level about 1,000 feet east of the shaft, are said to have been carried down to the flint, and to have shown ore to that depth.

A few hundred feet south of the Fourteenth street workings is one of the most important crevices in the region. It is known as the McNulty, or Avenue Top. The eastern portion of the crevice is now controlled by the Avenue Top Mining company, while the western portion belongs to the Bush Mining company.

The Avenue Top mine was first opened in 1875 by McNulty, Burt & Co. in search of lead. A large body of Galena was found on what is now the upper level, immediately east of the shaft, and 130 feet below the surface. To this day Galena may be seen running off in small flats between the ledges of clean Galena limestone. In the further search for lead a thin sheet of mineral was followed south 350 feet to the Black crevice, but it made nothing of value either in the north-south, or in the Black crevice. About midway two east-west crevices were crossed about thirty feet apart. A quartering a short distance north should intersect with these about fifty feet west and may make mineral. The general relation of these workings is shown on the accompanying ground plan, figure 85.

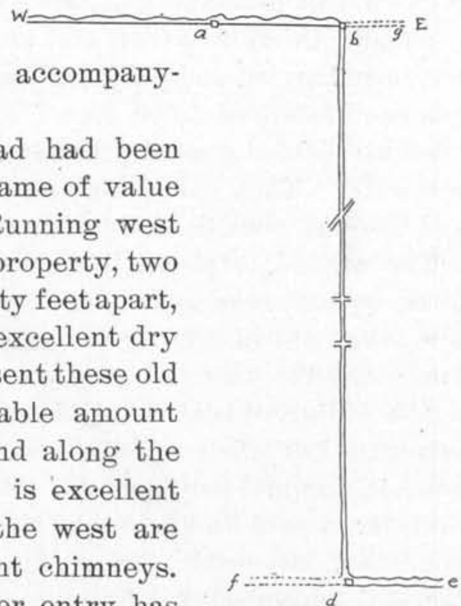


Fig. 85. Ground plan of Avenue Top mine.

Some years after the lead had been mined out, the dry bone became of value and work was resumed. Running west from the shaft to the Bush property, two levels were driven about thirty feet apart, and a very large amount of excellent dry bone was taken out. At present these old workings show a considerable amount of lean ore yet unmined, and along the bottom, in the water, there is excellent jack. These workings to the west are large and show very frequent chimneys. East of the shaft the upper entry has been opened up a long distance, but it did not yield so well. Eighty feet from the bottom of the shaft, a drop shaft, sixteen feet deep, connects with the north-south already mentioned as running over the Black crevice. On the ground plan, figure 85, this is represented at *b*. In the same figure *a* indicates the location of the main shaft, *g* the abandoned eastern workings in the McNulty crevice, *f* the closed upper western workings on the upper level of the Black crevice, *d* a second drop shaft, thirty feet to the present workings on the Black crevice, and *e* the forehead on the latter. In the east-west cross section of the McNulty crevice, figure 86, the letters correspond to those in the previous figure, *c* representing the bottom of the first drop shaft, the one connecting the main east workings with the north-south crossing.

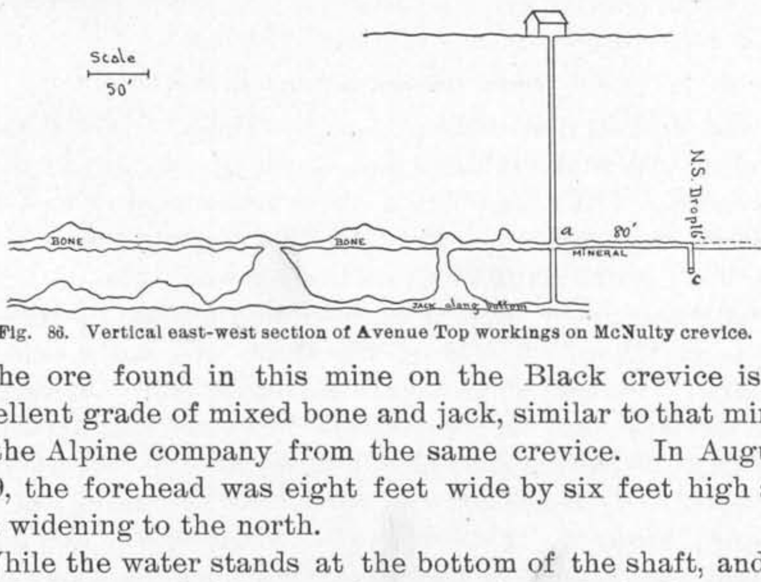


Fig. 86. Vertical east-west section of Avenue Top workings on McNulty crevice.

The ore found in this mine on the Black crevice is an excellent grade of mixed bone and jack, similar to that mined by the Alpine company from the same crevice. In August, 1899, the forehead was eight feet wide by six feet high and was widening to the north.

While the water stands at the bottom of the shaft, and at that level west, it is known that, east of the shaft, the ground is dry to a considerable depth. The present workings of the company on the Black crevice show no water, though sixteen feet below the water level at the main shaft. The work in this and neighboring mines indicates that there is a north-south bar approximately under Nevada street, and that east of that the water level is at least seventy feet lower than to the west. It is proposed to cut this bar and drain the western country, so as to allow the mining of the jack now in the water in the Avenue Top and Bush workings.

The Bush mine is located upon the western extension of the McNulty crevice, and the upper levels of the two mines have been driven through to connect. Figure 87 shows a verti-

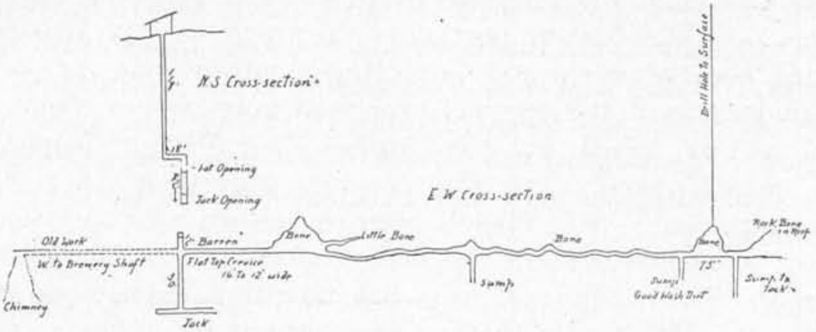


Fig. 87. Vertical cross-sections of the Bush mine, 1899.

cal east-west section of the present workings. Unfortunately the shaft was sunk eighteen feet south of the crevice to the top opening. At this point a level connects it with a drop shaft on the crevice proper. In the upper portion of the sketch is a north-south cross-section showing this.

Along the upper level a considerable amount of dry bone has been taken out east of the shaft, and some lean ore remains. Several sump shafts driven to water level show that the jack seen in the Avenue Top, runs west under this property. West the work is now stowed up, but it was formerly open to a connection with certain old workings near the Western brewery, from which a considerable amount of mineral was taken. At the time of the work the water stood up to the bottom of this upper level. Later work to the east has lowered this, and as a result a second level is now being run on the Bush ground thirty feet below. This level has a forehead approximately 4x5 feet in either direction, and is yielding a good grade of jack mixed with a little bone.

The Black crevice, already mentioned in connection with the description of the Avenue Top mine, extends from the edge of the bluffs west to the Brewery and beyond. It is a remarkably large open crevice, is said to have yielded 500,000 pounds of mineral at the Brewery, and 1,000,000 pounds still farther west. A portion of the crevice, under the Brewery grounds, was formerly used for a malting room, and certain famous underground dinners and dances have been held in it. One such dinner is described in the *Dubuque Herald* of August 22, 1860. The eastern portion of the crevice has yielded dry bone heavily and is now producing a mixed bone and jack. This portion of the crevice, except as noted below, belongs to, and is mined by, the Alpine Zinc Mining company. A certain portion of the crevice underlying the Dillrance property, is in dispute between the Alpine and Avenue Top companies, and in the meantime is in possession of the latter. The Alpine company has now four shafts upon the crevice. The quarry shaft at the eastern end produced four cars of bone in sinking the shaft, but it has never been worked to any extent. It is ninety feet deep. The Fifth street shaft is 155 feet to the bottom of the shaft, and 110 feet to the bottom of the top opening, in which most of the work has been done. The Alpine, which is the main shaft and is named from the street upon which it is located, is 127 feet from the engine floor, 140 feet from the loading platform to the bottom of the top opening, and about fifty feet below that to the present bottom of the mine. The Baxter shaft, located near the water tower and west of the disputed ground, is 110 feet deep and shows jack just above the water level. In all, the company holdings cover nearly a mile along this crevice.

For convenience in comparison the following table of elevations is inserted at this point:

ELEVATIONS OF SURFACE ABOVE SEA LEVEL.		LEVELS OF VARIOUS OPENINGS.					
Black crevice—							
Baxter	886	775					
Avenue Top	875			730		700	
Alpine	845				718		668
Fifth Street	815					705	660
Top opening exposed on Eighth St.					715		
Quarry shaft	745						655
McNulty crevice—							
Avenue Top	875		745		715		
Bush	855			729		700	
Fourteenth Street	820						650-670
Top of Galena exposed on Eighth St.	765						
Flint beds, top	645						
Probable base of Galena	560						

From a study of these figures it is evident that the heavy body of jack found in the Fourteenth street, the Quarry, Fifth street and the Alpine shafts all belong to one general horizon. The slight differences in level are no greater than occur along either of the crevices within the limits of a single mine. In a general way this horizon doubtless corresponds to the one commonly called the "third" opening, though the upper portion represents the "second" at the Alpine, and the "first" in the Fourteenth street mines. The next group of openings range all the way from 700 to 745 feet above sea level. Whether they are really the same or not is a question. In the Avenue Top work on the McNulty crevice the two openings chimney together and the top one has been connected with the top one in the Bush (729 A. T.). The lower one is called the "second" in the Avenue Top, and the "four foot" in the Bush, where it is thought to be above the true "second." As a matter of fact, it is slightly lower in the Bush than in the Avenue Top. The upper opening in the latter undoubtedly corresponds with the one seen in the quarry just off Eighth street and found at the same level in the Alpine workings on the Black crevice. The upper work in the same crevice on the Avenue Top ground is a little lower, and the lower work, where ore is now being mined, is several feet above the stopes now being driven by the Alpine. It is obvious that the opening worked in the Quarry shaft is really the lowest opening worked in the others, and that the opening in the Baxter, if the depth of that shaft be given correctly, is too high to allow it to be correlated with the work farther east.

The flint beds, which as elsewhere noted mark a probable ore horizon, lie below the jack openings worked, and the base of the galena, marked in Wisconsin by the "Pipe Clay" opening, will be found 92, 100, 105, 90 and 140 feet below the present shaft bottoms in the Alpine, Fifth street, Quarry, Fourteenth street, and Bush mines respectively.

The Alpine mine is at present the largest and best equipped mine in the district. It was worked for some years by the firm of Trueb, Southwell & Co.; but since February, 1899, it has passed under the present name. The equipment includes a power hoist, air compress or power drill, dynamo and a system of electric lights. The current from the dynamo is used for firing the shots. At present work is being carried west from the main shaft. The Fifth street shaft, some 500 feet east of the Alpine is equipped with a horse gin, but is not operated continuously. In sinking the Alpine shaft several thousand pounds of lead ore were found, but below, the ores have been zinc. Dry bone has been shipped for years from the upper opening. At the second opening, which is quite large and well developed, the ore pitches to the north and broadens out. There are indications of a similar pitch to the south, though the ore has not as yet been followed in this direction. The main stopes are accordingly now north of the shaft. A north-south cross section of the shaft, showing its relations to the ore, is given in figure 88. At present the stope is sixteen feet wide and the face twenty feet high. The ore has been followed approximately 400 feet west or to the disputed ground. The bottom shows even better ore, clearer jack and less bone. In the Fifth street and the Quarry shafts the same ore body is found at the proper horizon, while at the Baxter shaft good ore occurs nearly 100 feet above this level. The Alpine workings, and those east of that shaft, are east of the bar already mentioned, and accordingly are not troubled with water. There is evidently a very large amount of good ore yet to be mined here, and under the present active management the property may be expected to develop into an important mine.

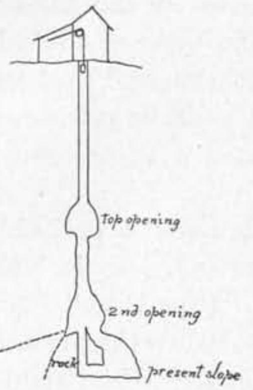
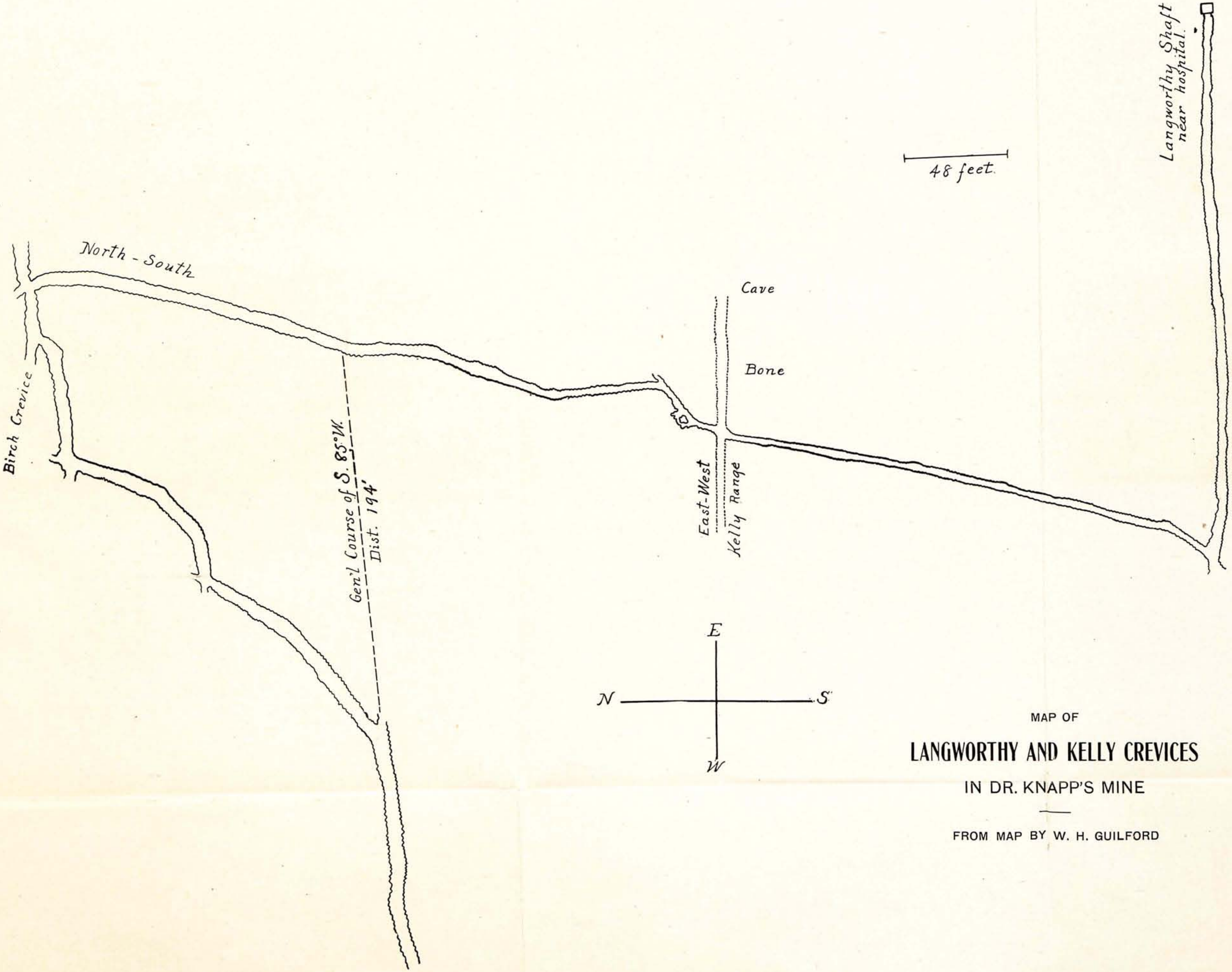


Fig. 88. Cross section of Black crevice at Alpine shaft. 1899.

About 150 feet south of the Black crevice is the Fanning, which was very extensively worked in 1856-57. More than 200 men are said to have been employed upon it at that time. It is not worked as far east as the Black crevice is. Three hundred feet beyond it, and nearly parallel, is the Aulkner, which is estimated to have yielded about 2,000,000 pounds of mineral. To the east this crevice loses its identity, and to the west, it with the Fanning, Black, McNulty andother crevices of this group, runs into the great country of open underground work known as the McPoland pond.

Langworthy and Kelly.—South from the group of crevices just described the next important group is the Langworthy and Kelly. As usual these crevices were, some years since, worked for lead, but they are now open as zinc mines. They are about 300 feet apart, and the Langworthy has been worked for several miles along its course. It is said to have yielded about 6,000,000 pounds of galena. The Kelly has been worked from the cathedral west into section 27, where there are a number of quarterings connecting it with the



MAP OF

LANGWORTHY AND KELLY CREVICES

IN DR. KNAPP'S MINE

FROM MAP BY W. H. GUILFORD

Langworthy. It closes up tight at intervals, but, altogether it has proven a most reliable crevice. Up to February, 1854, the Langworthy, Kelly and Cardiff were estimated to have yielded some 10,000,000 pounds of mineral. The Langworthy is occasionally known as the Hancock.

At present these crevices are being worked at three points. Near Mercy hospital Dr. H. G. Knapp has an excellent body of jack ore on the Kelly, entrance being through the Langworthy as shown on the accompanying map. West of here a new company is at work on the Langworthy, and on Brad street Boyle & Company are working the same crevice for dry bone.

At the Knapp mine the jack is found on the Kelly at a depth of 147 feet from the surface, or 110 feet in the rock. This would place the ore body at about 660 A. T., or about the same level as the jack found in the Alpine and neighboring mines. The work is east of the bar before mentioned and is accordingly dry. When visited in the fall of 1899, the entry was approximately sixty-five feet long in an east-west direction. At the east end the face showed a body of jack widening from a few inches only in the roof to about three feet at the bottom, the entry being seven feet high. A sketch of the ore (figure 89) as seen in the roof seam is given below, *a* representing clear white crystals of calcite, *b* the crystalline calcite commonly called tiff, *c* the black blende showing occasional faces of the rhombic dodecahedron, and the whole surrounded by ordinary earthy dolomite. The ore consists of a dolomite much cut by solution, with the solution cavities later filled with blende. It is one of the cleanest and best ores so far mined in the region. The vein shows as usual no sign of faulting, selvage or other phenomena common to the fissure veins of the west. West of the drop shaft by which the jack is reached, the cap rock is well

Fig. 89. Blende and calcite in the Kelly range.

developed though the crevice shows plainly. Beyond this the jack is mixed with a little bone. The blende was found by means of a drop shaft from the old mineral and bone workings on the Kelly, which are thirty feet above its level. These workings are the ones shown on the accompanying map (Plate IX) reproduced here to give an exact idea of the way these crevices run. The map is from surveys made by Mr. W. H. Guilford and is published by the courtesy of Dr. H. G. Knapp.

On Brad street the Langworthy crevice is being worked by Boyle & Company for dry bone. The accompanying sketch map (figure 90) is a ground plan of their workings as they existed in the summer of 1898. The shaft now open is located on a north-south some forty feet east of the intersection of two important crevices which come together at a low angle. Some years ago a shaft was opened at this intersection and the mine was worked for mineral. The dry bone was discovered at that time, but as it had no value the entries were driven through it and the material excavated was dumped into swamps and stowed as waste. Along both of the crevices there are frequent chimneys running up six to twenty-five feet. Where there are no chimneys the crevice is sixteen inches to four feet wide, with a flat cap rock showing a narrow vertical seam. The crevice opens occasionally to a width of ten feet. The walls show weathered Galena limestone in ledges

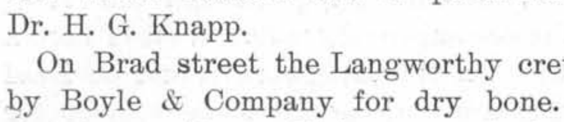


Fig. 90. Bradstreet mine on Langworthy crevice.

about ten inches thick, the weathering having proceeded farther along the bedding planes. The dry bone makes in flats along these planes, resembling in appearance and position the cherty partings usual in limestone formations. Much of the crevice is filled with a breccia composed of blocks of Galena limestone fallen in from the sides. One piece, 1x3x4 feet in diameter, was measured. These blocks

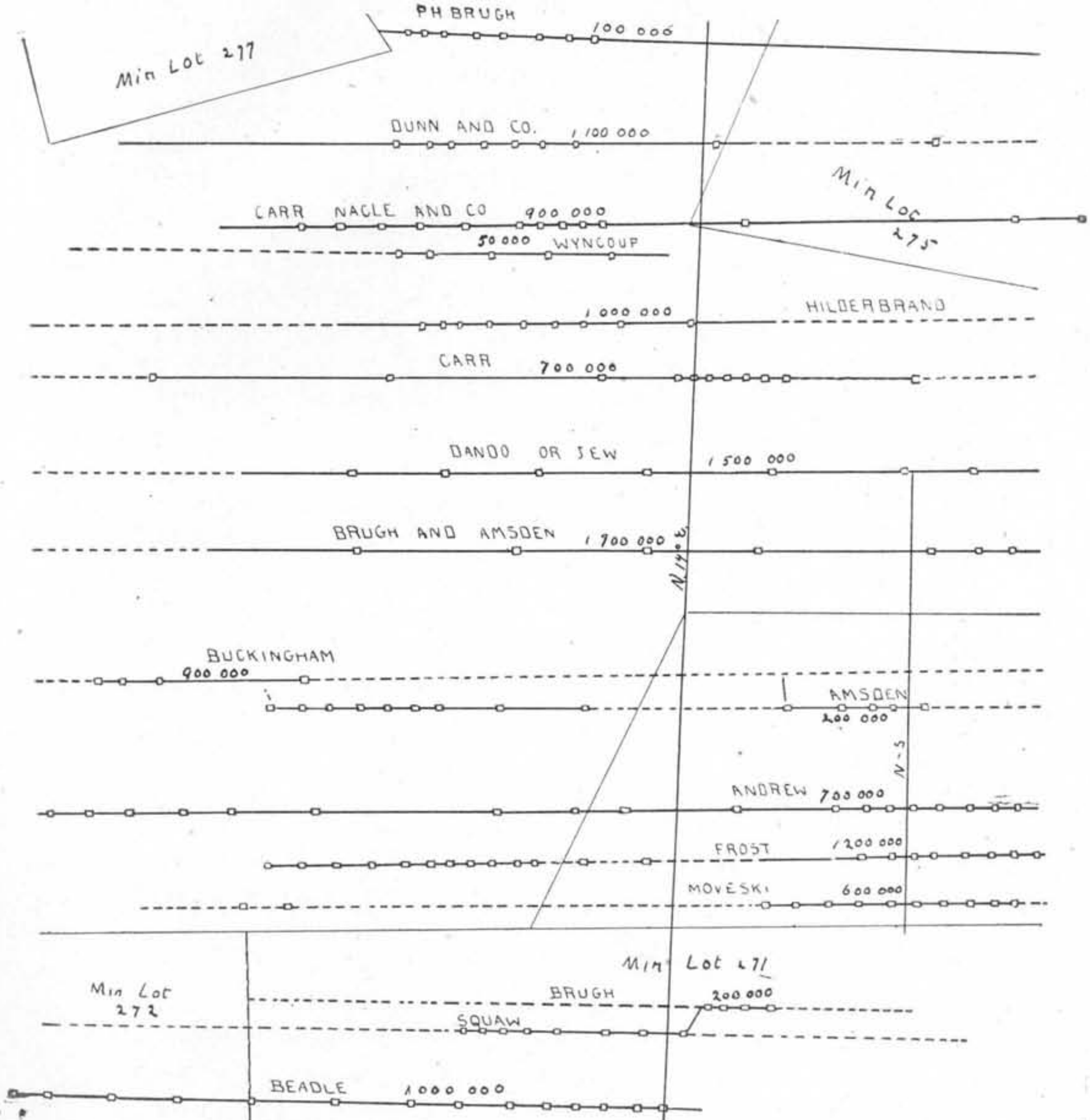


Plate X. Sketch map of main crevice in the Pike's Peak region.

stand at all angles as in a talus heap. Occasionally a block is level and continuous with the bedding at the side, being supported by narrow rock pillars. The matrix of this conglomerate is largely dry bone. There is also much ochre; and where water runs down the sides they are coated with calcite. There are no signs of galena, blende or pyrite. There is a considerable amount of coarse dolomitic sand, occasionally showing cross-bedding. Apparently, as the walls weathered back, the harder and undissolved pieces of rock caved in. These were later cemented by dry bone, and finally freely moving waters deposited mechanically the dolomitic sands.

Rabbit Hollow mines.—South of the Langworthy there are a number of important crevices among which the Slater, Peacock. Madden and others may be mentioned. Near the end of the Dodge street car line there are a number of small mines, among which the one known as the Rabbit Hollow mine is at present the most important.

Center Grove mines.—In the general vicinity of Center Grove (Sw. ¼ Sec. 27) there has been more or less mining for years. On Mineral lot 243, a large number of shallow shafts were, at one time, opened for lead. These were so close together that at present the lot looks as if it had been completely burrowed. The Slater crevice is now opened up on the Luther place and has yielded some mineral. A number of good crevices are known to underlie the Guilford land, Mineral lot 237. Between here and the end of the street car line are a number of small prospects, and the Sevastopol or West Dubuque mine, a former heavy producer, is now being reopened.

Pike's Peak.—This name is applied to the mines occurring on the Se. ¼ of Sec. 33 and the adjacent lands. The name had its origin in the circumstance that the mines here were discovered and extensively worked for lead about the time of the Pike's Peak excitement in Colorado. A sketch showing the general location of the leading crevices with their estimated production, as compiled by Mr. W. H. Guilford and Mr. J. R.

Miller, is given in Plate X. Some of these crevices are known to extend under the land to the east and west, and others are as yet unproven under the adjacent territory. All of these crevices were extensively worked for lead ore, and in many of them good ore was left in the bottom when the work was abandoned because of the water. In others black jack is known to be present in quantity.

In 1899 a partnership under the name of the Pike's Peak Mining company, undertook to unwater some of these mines for the zinc ore. A pump was installed on the Brugh and Amsden range, and later an old shaft on the Dando or Jew was opened up. The pump had a rated capacity of 300 gallons per minute and after a few weeks took the water level down sixty feet. This uncovered some galena and a considerable amount of black jack. The latter occurs in solution cavities in the blue Galena limestone, mixed with pyrite and the galena, mixed with some blende, is below. Similar ore is found on the Jew crevice. Several hundred tons of the ore have been raised, and considerable bodies have been proven. The ore must be concentrated before it can be used, and the large amount of pyrite present makes it difficult to make a clean concentrate. Many of the other ranges are known to be valuable and will be opened up.

On the Locky land, north of Pike's Peak region proper, are the Old Rock Lead, the Locky and other crevices, including one worked by Messrs. Hird. These crevices have all yielded dry bone and show more or less jack. An effort is now being made to unwater the Locky for the sake of the blende. A lift pump driven by horse power has been installed, and a good body of jack and bone has been uncovered.

Other crevices.—In addition to the crevices and mines specifically described there are a large number of others, including the Floyd, Goose, Horn, Smith and Stewart, Booth and Carter, Ames, McNair, McKenzie, Iron Rust, Driscoll and McNamara, the Whisky Hill or Seminary ranges, the Peru diggings and the Rockdale and Key West mines. Among the latter the Kane Bros. mine, opened in 1898, is interesting and important. This mine is located at the eastern edge of Key West and at the head of the Rockdale hill. A sketch of the workings, as open when visited in 1898, is shown in figure 91. The mine is now reached by means of the shaft *a*, which is about fifty feet deep. This one was discovered, however, by crawling in along the crevice *f* from some old workings to the east. The east-west crevices are connected by narrow north-souths, such as *e* and *d*. At the drop shaft, at the north end of *e*, there is a difference of five feet in level, the northern openings being higher. This portion of the workings lies about six feet below the top of the Galena limestone, but west from the main shaft *a*, the work rises, and at *b* the shales themselves form the roof of a small cave.

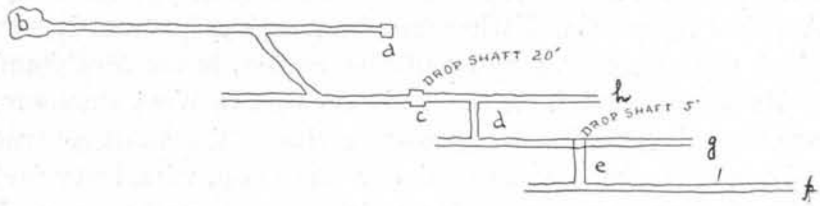


Fig. 91. Ground plan of Kane Bros. mine.

Galena was found along the crevice from *a* to *b*, but the main mineral comes from the crevice *h*. This opening is made by two parallel crevices, as is indicated in figure 92. The roof is flat, the cap well defined, and the two crevices show above as mere fractures. A drop shaft at *c* shows the presence of a key rock dividing the two as they go down. When first discovered *h* was an open space three to five feet wide and twelve to twenty-four inches deep with loose dolomitic sand in the bottom. The walls and roof showed clusters of galena crystals, and pieces of mineral were found on and in the sand. From a distance of some forty feet approximately 50,000 pounds of mineral were taken. The ore may still be seen in this and the other crevices in thin sheets, running out along the bedding planes, and in druses in the cap and wall rocks. Bits of the rock broken open show pieces of mineral in apparently undisturbed dolomite. The galena usually takes the form of cubes, occasionally with octahedral truncations. It occurs in large crystals, some of the cubes having three inch faces. The present workings are considerably above the ordinary first opening level. Whether open ground will be found below is as yet unknown.

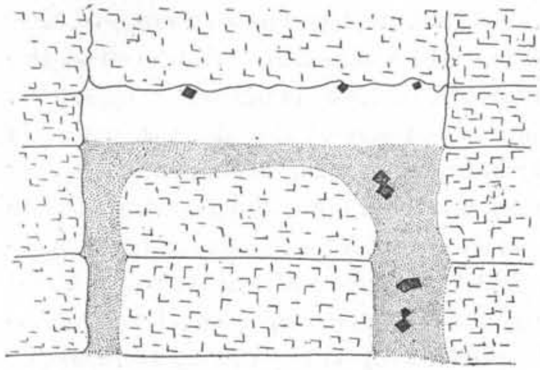


Fig. 92. Occurrence of galena in Kane Bros. mine.

Another interesting little mine, interesting, because it is so typical of the general work of the region, is the McPoland and Basler, visited in 1898. It is located in West Dubuque, near the end of the Julien avenue car line. The shaft is three by six feet in cross section, ninety feet deep, with forty feet in the Galena limestone. It is timbered down to the rock with two-inch lumber placed on edge and staid in place with one-inch strips. A ladder fastened to one end, a windlass, rope and bucket, a board roof supported on poles at the corners, and a few picks, shovels and hand drills, complete the equipment. Two men work the mine. One stays above and hoists, the other works below, drilling and tramming out the ore and rock. The figure (93) given below shows the plan of the work which follows various small crevices. The numbers give approximate distances in feet. Running southwest, a sheet of

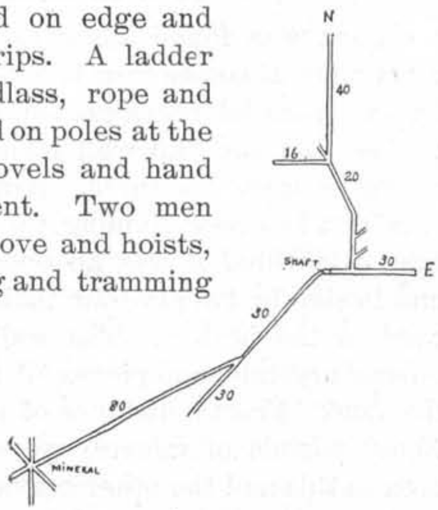


Fig. 93. McPoland and Basler mine.

mineral, one-half an inch thick, was followed. It lay between dolomitic walls which were softened and weathered to a sandy consistency for a total thickness of about three inches. This was picked out by the miner, much as a shearing cut is made in coal mining, and then a blast was placed so as to break the rock towards the cut. In this way an entry, about five feet high by two wide, was driven at a cost of approximately $1 a foot.

At the extreme southwest of the mine, as sketched (figure 93), an intersection of several crevices was discovered where the rock was badly decayed and contained considerable mineral. This showed usually as cubes and was in softened and weathered portions of the dolomite. For example in figure 94, *a* represents the galena, *b* the sandy dolomite and *c* the weathered rock. Here, as in the narrow sheet, it seems that the ore was deposited in the rock before the weathering took place. This is the more evident in the case of the vertical sheets where the mineral has the exact form of the common narrow cracks and the plane between the sheet of mineral and the country rock would be a natural one for the circulation of water and consequent decay of the rocks.

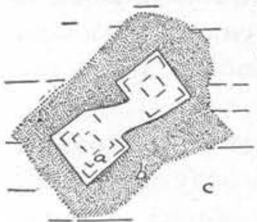


Fig. 94. Occurrence of galena in McPoland & Basler mine.

Mines away from Dubuque.—While the main mining has been done in the immediate vicinity of Dubuque, there are traces of mineral at other points in the county. At Sherrill Mound and elsewhere in Jefferson township a considerable amount of lead has been taken out and at the first named place the old dumps show the presence of dry bone and black jack. In Mosalem township, near Rice's and Ball's caves, there is abundant float, and some ore has been found. In regard to these and other cases it can only be said that no important ore bodies have yet been developed. The region is similar, in all essential particulars, to that near Dubuque where the heavy ore bodies occur. It is not unlikely that adequate prospecting would develop important leads, but here, as near Dubuque, it is to be expected that the ore will be irregularly distributed and that much of the rock will be barren. While traces of minerals are everywhere common, the concentration of minerals to form ore bodies is, in the nature of the case, exceptional. It is dependent on many causes, and their action is so varied that it is impossible always to predict just where one will occur.

ORIGIN OF THE DUBUQUE ORES.

It will have been evident from the pages preceding that the Dubuque ores are believed not to have had their origin in deep-seated causes, but to have accumulated under the influence of agents active relatively near the surface. In considering the evidence upon which this belief is founded it is convenient to discuss, *a* the ultimate source of the metals, *b* the causes of the localization of ore bodies, and *c* the methods of concentration.

Ultimate source of the ores.—The limestones and dolomites of the region, even when far from any known body of mineral, and when quite barren when examined by ordinary methods of analysis, still show notable percentages of both lead and zinc when tested by the large quantity methods used by Winslow and Robertson.* In table I the results of such tests as made by Dr. J. B. Weems are given. While the percentage of the minerals is in no case large, the total amount by acre or square mile of the formation, assuming that they represent average conditions, is quite sufficient to account for the largest leads in the region.

* Missouri Geol. Surv., Vol. VII, pp. 740-742.

TABLE I—ANALYSIS OF DUBUQUE LIMESTONES AND DOLOMITES.

	Analysis No.	H_2O	Insol.	CaO	Fe_2O_3	SO_3	P_2O_5	Mgo	CO_2	Org.	Total.	Dolomite.	Limestone.	Excess CO_2	Less CO_2	PbO.	Pb.	ZnO	Zn	Rock No.
Blue rock from Halpin mine at depth of 40 ft. in Galena.	37	.06	1.55	30.23	.82	1.52	.45	19.39	45.19	1.42	100.63	88.89	5.83	.09	....	.00633	.00587	.00090	.00072	304
Niagara, Cascade, Iowa	38	.26	11.34	27.19	.81	....	.60	17.78	41.46	.82	100 26	77.13	8.80	.50	....	.00567	.00525	.00020	.00016	305
Lower buff beds, Sageville, Iowa	39	.10	1.08	30.78	.90	....	.64	18.34	44.37	3.41	99.62	84.39	9.14	...	....	.00501	.00465	.....	......	306
Trenton limestone, Sageville, Iowa	40	.04	7 63	50.15	.62	....	.61	1.21	39.56	.77	100.59	7.62	86.26	...	2 96	.00611	.00567	.....	......	307
"Upper thin beds," section 33, Dubuque Tp	41	.06	5.23	28.95	1.15	....	.46	18.54	44 00	.96	99 35	83.01	7.61	.87	....	.00302	.00280	.00050	.00040	308
Niagara, Sherrill's Mound	42	.05	3.24	30.01	.74	....	.52	18.99	44.91	1.34	99 80	86.71	6.75	.45	...	.00065	.00060	.....	......	309
Galena below cap rock (1st opening) Tibey quarry	43	.05	3.33	34.56	1.26	....	.37	15.30	43 34	1.25	99.46	76 08	19.07	...	1.65	.00109	.00101	.....	......	310
Lime burning rock, Eagle Point	44	.02	2.15	30.72	.82	....	.60	19 90	45.91	.13	100.25	94.14	2.47	...	.08	.00155	.00143	.....	......	311
Non-lime burning, Eagle Point	45	.04	8.63	28.86	.85	....	.51	18.82	42.08	1.07	100.86	84.13	6.92	...	1.29	.00221	.00204	.00170	.00136	?
	..	...	.....	.....	....	....	...	.....	.....	....	......	....	.....	...	....	Avg.	.00326	.....	.00029	
	..	...	.....	.....	....	....	...	.....	.....	....	......	....	.....	...	....	*	.00376	†	.00043	

*Avg. PbS. †Avg. ZnS.

NOTE.—1 Cu. ft. rock 170 lbs.
2,269,664 tons rock per sq. mi. 1 foot thick.
Galena—95.33 tons per sq. mi. 1 foot thick.
Blende—9.76 tons per sq. mi. 1 foot thick.
Galena—19,066 tons per sq. mi. 200 feet thick.
Blende—1,952 tons per sq. mi. 200 feet thick.

These widely disseminated and minute quantities of the metals are obviously susceptible of two interpretations. In all mineral districts, even where the veins are most persistent and sharply defined, there is a greater or less tendency for the ore to spread out from the veins proper and impregnate the country rock. In a region much cut up by veins the country rock may become so thoroughly mineralized that it may itself be an ore. In the Cripple Creek district much of the ore is of this character,* and the phenomenon is so common that examples need not be multiplied. Wherever there is underground water there are chemical changes and rearrangements taking place in the rocks. No body of rock is stable and constant in composition, and in rocks, such as limestone and dolomites, which are easily soluble, the amount of change possible and commonly occurring is very great. In the presence of sulphides and water, carbonate rocks are susceptible of many changes; and in the region in question the sulphides are widely distributed, and underground water has already been shown to be an important factor.

It is clear that the action of circulating waters may be either toward dissemination or toward concentration of a particular substance, and that this action will depend upon a number of factors, including the chemical character of the substance, of the water and of the country rock, and the rate, direction, constancy and duration of flow, and the temperature and pressure of the circulating solution. A set of conditions under which ore occurring in definite veins might be conceived to have become thoroughly disseminated is so possible that doubtless much ore even in the region under discussion has been so distributed. It is not, however, believed that this is true of the bulk of the disseminated ore. In order to make such a case conclusive it would be necessary, first, to demonstrate that the vein fillings were themselves original, and were not due to lateral segregation, since the process of concentration is quite as common and easy

*Penrose: Sixteenth Ann. Rep. U. S. Geol. Surv., pt. II, pp. 145-146.

of occurrence as that of dissemination. If the vein deposits of this or any other ore district be definitely proven to have their genesis in deep-seated causes, then the probability is that any disseminated ore has been carried out from them, and in such a case it would be expected that the quantity of ore so found would regularly decrease with the distance from the vein. In any other case the burden of the proof is upon those who hold the widely disseminated and minute quantities of the metals to be wholly secondary. Against such a view there are certain objections which may be justly urged.

In the first place, it is a well established fact that minute quantities of all the common metals occur in sea water. Dr. J. R. Donn† has recently investigated this question afresh and has confirmed the other findings. If such metals occur in minute quantities in the sea it is difficult to understand why they should not be supposed to occur in minute quantities in sedimentary rocks which are formed in the sea. If calcium and magnesium, which occur in larger though still small quantities in ordinary sea water, can be deposited either by chemical or other agencies, why not lead, zinc and iron? The mere statement of the case is sufficient to show the inherent probability of its occurrence. Again, in some of the analyses quoted, and in others given by Winslow and Robertson,‡ the metals are found in rocks miles from any known or probable vein deposit. In ordinary field work nothing is more common than to find small quantities of metallic sulphides in undisturbed rocks, wholly outside known mineral regions. Such an instance is the occurrence of blende and of millerite, as reported by Keyes§ at Keokuk, and the recent finding of small quantities of blende in Van Buren county. Blende occasionally occurs in the septarian nodules of the coal measures; and the sulphide of iron is one of the most widely distributed of minerals. To assume that all of these occurrences are due to a wandering of the ore from

†Trans. Amer. Inst. Ming. Eng., Vol. XXII.
‡Missouri Geol. Surv., Vol. VII, pp. 479-482.
§Iowa Geol. Surv., Vol. I, p. 187.

some vein deposit requires better proof than has yet been given. While it may be true that it is impossible to prove the absolute originality of the metallic sulphides, except when found in the basic constituents of pyrogenetic rocks, yet something must be allowed to probability, and up to the present it would seem that the evidence may justly be interpreted to mean that, except when found in definite association with veins of known or probable deep-seated genesis, disseminated metals are probably original.

Localization of ore bodies.—Granting for the moment that the metals in the present case were originally disseminated throughout the rocks of the district when the latter were formed, it is pertinent to inquire why the ore bodies are confined to somewhat definite areas separated by apparently equally favorable but practically barren ground. This phenomenon is one which has been noted by all previous workers, and has been the chief stumbling block in the way of accepting the hypothesis that the ores originated by the general process known as lateral secretion. It is the one feature of the region not easy to explain on such a hypothesis, but it admits of ready explanation if the ores be considered as of deep seated origin.

The present distribution of the ore districts must be due to causes operating either at the time of original deposition or during the period of concentration. Either the areas now found to be ore-bearing were particularly favorable to its deposition, or by peculiarities of structure or position they have favored the concentration in them of the metals disseminated through the rocks of the surrounding area. If the ores were formed in deep seated veins and came up from below in solution or otherwise, the contrasted richness and barrenness of neighboring areas would be but the natural results of the presence or absence of fault lines deep enough to communicate with the sources of supply. If the ore be conceived to have originated through lateral secretion, fault planes, if present would still afford the most favorable situations for the accumulation of ores as Spurr has excellently shown in his studies of the Aspen district.* Fault planes cutting across the area and extending to considerable depth, breaking up and fracturing the rock often for some distance on either side, afford excellent opportunity for the movement of water and consequent concentration and deposition of ores. Probably also the bringing into juxtaposition of two sorts of strata of diverse composition opens up the way, under the influence of water, to a considerable amount of chemical activity. It has already been shown, however, that in the Dubuque area there are no faults of any importance, and while, according to Blake, certain of the Wisconsin lodes have been influenced by faulting, the Dubuque area proper is remarkably free from faulting of any kind. The region as a whole is a notable exception to the mineral districts of the world in the absence both of igneous intrusions of any kind and of anything but the simplest structure. The great crevices which run through the region belong rather to the category of joint planes. They have doubtless influenced the flow of underground waters and have in so much determined the localization of ore bodies. They are grouped along certain low anticlinal axes, but crevices apparently quite as favorably situated are barren, and so far as present studies go this grouping parallel to the almost insignificant anticlines can not be considered to be the whole explanation. It has probably influenced, in a manner, the secondary accumulation of the ores, but there are reasons for believing that there were inequalities in the primary distribution. Whitney, recognizing the difficulties of the situation, suggested that the metallic sulphides were thrown down in particular abundance in those portions of the sea particularly charged with living forms. To this it is sufficient answer that there is no known relation in the rocks between abundance of fossils and ore. If there were the Trenton should be more mineralized than the Galena, whereas the reverse represents the facts. It is true that the evidence of

*Mon XXXI, U. S. Geol. Surv.

former life in the Galena has been to some extent obliterated, but it is doubtful whether the Galena ever was as fossiliferous as the Trenton now is, and it is certain that the Receptaculites and gastropod horizons which persist through the Galena are nowhere associated with notable ore accumulations.

The oil shale occurring at the top of the "glassrock," and commonly forming the base of the Galena, is an exception, in that it is usually fossiliferous, and at the same time is a reliable ore horizon. It has already been suggested, however, that its action may have been entirely secondary in arresting the downward flow of ore-bearing solutions, and Blake has furthermore suggested that the hydrocarbons in it may not necessarily be due to the decay of plants and animals.*

Chamberlin† has appealed to the probable ancient geography of the sea bottom and the action of various currents in the accumulation of sea weeds in particular areas, with the consequent evolution of hydric sulphide and the precipitation of metallic sulphides. This hypothesis necessarily implies a large amount of speculation, and is one difficult either to prove or disprove. It assumes a point of which we have no evidence other than the ores themselves, namely that there was a particular accumulation of hydric sulphide in these areas.

Mr. Arthur Winslow, in his explanation of the Missouri ores and by implication of those of Iowa and Wisconsin, would make the whole matter secondary and dependent upon the irregularity of processes of accumulation.

In considering the matter it seems significant to note the association here, as is common elsewhere, of the ores of lead and zinc with great bodies of dolomite. This association has been so frequently noted that it is hardly necessary to cite examples. In the region in question there are no important ore bodies except those in the dolomite, or those secondarily

*Trans. Amer. Inst. Ming. Eng., Vol. XXII, p. 629.
†Geol. Wisconsin, Vol. IV, p. 529.

derived from it. This is true as well of the ores in the Lower Magnesian or Oneota, at Lansing, and on Mineral creek in Allamakee county. The great bodies of disseminated lead ores at Mine La Motte, Bonne Terre, Doe Run, Flat river and other localities in southeastern Missouri are all in dolomitic rock. The ores of central and southwestern Missouri are in some cases in dolomite and in others are supposed by Mr. Winslow to have been secondarily derived from the decay of a series of rocks which must have been largely dolomitic. The silver-lead ores of Leadville* are in dolomite, and those at Aspen† follow the same rule. Indeed it would be easy to give a long list of such occurrences. The association has been frequently noted before but has not been considered of primary significance.

The opportunities for secondary association of the ores and dolomite are numerous. Dolomite is itself a porous rock and its homogeneity, as has already been shown, causes it to fracture in a few extensive planes rather than many of limited extent. It is therefore particularly susceptible to the changes which come from the circulation of waters through rock, and forms a ready habitat for ores. Being readily soluble, and carrying lime and magnesia, it affords quantities of these substances which may, in some instances, be important primary or secondary chemical agents in the deposition of ores. It is a rock which may readily be conceived to selectively absorb ores from a solution coming from any ultimate source. It is particularly susceptible to metasomatic replacement. These various facts have been held to be sufficient grounds for the association of dolomite with lead and zinc ores. A consideration, however, of the conditions under which dolomite is formed, offers the hypothesis that these conditions are themselves favorable for the primary deposition of metallic sulphides in minute quantity. In the particular

*Emmons. Mon. XII, U. S. Geol. Surv., p. 375.
†Spurr. Mon. XXXI, U. S. Geol. Surv., p. 206, et seq.

case in hand it has been shown that the dolomites accumulated in shallow, isolated basins, free from the incursion of fresh water, and exposed presumably to active concentration by evaporation. This concentration progressed so far that the magnesia became notably in excess and was deposited, entering into combination with the underlying, newly formed limestone, itself formed probably by ordinary means before the period of evaporation. It is clear that, in concentration by evaporation, not only would the per cent of magnesia be raised above the normal, but the same would be true of all other salts in the sea water. The lead, zinc and iron, brought down from the adjacent Archean land mass, perhaps as the soluble sulphates, would themselves be concentrated. Whatever of reducing agents were present in the water would be increased, not in quantity, but in percentage, and accordingly in effectiveness, under which conditions the reduction of the sulphates and the deposition of the sulphides in the quantity in which they are now known to be present, is certainly quite within the limits of probability.

The conditions outlined, inasmuch as the concentration was in shallow water, probably was not uniform either in time or position, and that the precipitation should have been irregular to an equal degree is quite to be expected. The irregularity, following no known law of present position or structure, and yet secondarily influenced by the latter, exactly fits the facts of the field. These secondary changes have been so numerous as somewhat to obscure the original conditions so that a series of analyses fails to show as direct a relation between the degree of dolomitization and the percentage of disseminated metals as the hypothesis suggests. The broader field studies show, however, that the most perfectly dolomitized areas, if the factors controlling concentration be favorable, are the ones which have yielded and are yielding the largest amounts of ore. While perhaps the truth of the hypothesis cannot at present be clearly demonstrated, it is believed that the facts are sufficient to warrant its acceptance as a working hypothesis to be farther tested and perhaps changed.

In the matter of the possible derivation of the ores below, it can only be stated that no sufficient evidence has yet been advanced for a belief in such a genesis. No veins are known to run to anything more than a limited depth; the veins worked have none of the usual characteristics of the "true fissure veins." There is practically no faulting and no intrusive rock at all. The ores could not have come up from below, except in solution, and it is difficult, if not impossible, to conceive of their crossing the great aquifers of the Saint Peter and Saint Croix sandstones below without becoming diffused, and yet these rocks never show any signs of mineralization. Furthermore, if any of the ores of the district have had such a genesis it will be conceded that the sulphides occurring in vein form would probably be the ones, yet the blende so found is characteristically black through the apparent presence of organic matter, showing that it must have been deposited in the presence at least of surface agencies. These facts, with an adequate hypothesis accounting for the deposition and concentration of the ores under ordinary conditions, throw the burden of proof upon those, if any, who would appeal to what, for this region, is certainly an extraordinary hypothesis.

Concentration of the ores.—The metals, as originally precipitated, were so widely disseminated that they would never have been of value, and probably never would even have attracted attention. It is not thought that, in this district at least, there are any bodies of workable ore except as a result of local concentration. The general process of concentration or aggregation has probably been that of the oxidation of the disseminated sulphides by ground waters percolating through the rock, the transmission of them as sulphates to the crevices, and their redeposition there as sulphides by the waters reaching the cavity by a more direct route and charged with reducing agents, with the secondary reduction of the sulphides by each other. The different crevices carried probably somewhat different solutions, and a crevice which is not itself ore-bearing may make another valuable where the two intersect. In the Stewarts cave, for example, the north crevice has not so far been found to carry much ore, but wherever there is a north-south crevice connecting it with the parallel crevice to the south, a bunch of ore has been found in the latter. The north crevice has indirect communication with the surface through the Timmons, and receives its waters after they have penetrated decaying vegetation and organic matter, while the south crevice is charged with solutions which find their way to it after a devious course through the porous rock itself.

The secondary changes which have resulted in the large change of the sulphides to oxides and carbonates have already been discussed.

The question naturally suggests itself, in view of the known presence of large amounts of artesian water in the rocks below, whether this water might not have been either the source of the ore or the precipitating agent. The following analyses of water frcm the level, representing the general character of the water in the mines, and from the artesian wells themselves, together with the analyses already quoted of water from the Saint Peter sandstone, negative this view. The character of the artesian water shows that it is not the same as that found in the mines, a fact confirmed by the irregular level to which the mine water rises and the constant horizon of the artesian waters. It is also apparent that the mine water is not a mixture of artesian and surface waters, nor that one would be likely to have precipitative influence more than the other. The two waters have much in common because they traversed much the same sort of rocks. The analyses quoted were made by Dr. Floyd Davis, and are given by the courtesy of Messrs. Robert and W. W. Bonson:

	PARTS PER MILLION.	
	Eagle Point (Artesian).	Level mine water.
Total solids	308.000	393.000
Nitrogen in nitrates	None	.060
Chlorin	5.750	3.875
Sulphuric anhydride	13.300	52.180
Silica and insol	113.460	13.360
Oxygen in iron and aluminous oxides	None	None
Lime CaO	82.800	108.060
Magnesia MgO	58.300	65.220
Sodium chloride	17.500	28.700
Potassium chloride	1.280	....
	GRAINS PER GALLON.	
Silica and insol	.785	.779
Potassium chloride	.075	....
Sodium chloride	.494	.372
Sodium nitrate	....	.014
Sodium sulphate	.637	1.557
Magnesium sulphate	.630	3.349
Magnesium carbonate	6.689	5.713
Calcium carbonate	8.622	11.232

The cause of deposition of ore is doubtless, in detail, the meeting place of diverse currents or flows of water, but in a broader way it is determined by the surface of permanent underground water level. Below the surface of any region is a second surface which reflects all but the minor inequalities of the overlying topography, and which is the surface of ground water. If one dig a well he normally passes through some feet of dry or moist earth but below that comes to a level at which water stands in the well. On top of a hill this level may be but little if any deeper as measured from the crest than on the hillside or on the bottom land. Very deep valleys, however, cut this level, and springs mark the horizon. Peculiarities of structure may cause the water level to be cut by relatively shallow valleys, or springs may occur well up on the side of the hill. Normally, however, the water level slopes down on approaching a stream so that the latter barely cuts it. As a result springs are apt to be at the base of the river bluffs, and many shallow valleys do not cut the ground water level at all. It is a broad sheet underlying the rocky surface, and if at any point it be penetrated, water is secured. In wet weather this horizon rises, and in long dry seasons it sinks, and wells must be driven deeper to overtake the receding surface.

If powerful pumps be installed at any point the horizon may be lowered at that point, unless the rock be so porous that the water flows as fast as it is pumped out, an unusual condition under ordinary structural conditions, since the rate of flow through even porous rocks is very slow. The waters which fall on the earth in part are evaporated, in part run off over the surface, and in part sink down to this underground water surface. Beyond that point the movement is very slow, so slow that the waters are almost stationary, though there is none the less a constant movement through the rock to lower outlets. The waters lie there practically dormant and become charged by solution with the various salts disseminated throughout the rocks. They largely lose the oxygen and other elements with which they were charged when they started to seep through the ground, and become practically reducing agents. The surface waters constantly coming down to this horizon, having traveled with relative rapidity through a narrow zone of rock, are charged with somewhat different elements, and, at the meeting place of the two, precipitations and other chemical changes are relatively active. From time to time changes in the altitude of the land, in the amount or rate of precipitation, in the temperature or other climatic conditions, raise or lower the ground water level, and there is accordingly here a zone through which chemical action is constantly taking place.

At a still lower level there is a second zone of importance in the genesis of ores. Near the seashore, a hole dug in the sand encounters sea water at about the level of the same water in the sea; allowing for structure and other modifying conditions, the same thing holds true of a hole 1,000 miles inland. In the latter case, however, the sea water is found a little above the sea level proper, at the level of no flow. That is, when water sinks to this level, gravity ceases to impel farther flow; they have practically reached the ocean though it was reached by going straight down. Above this level and that of the ordinary ground water there is a zone, broad or narrow as the case may be, in which the waters have a slow movement and in which they are influenced by the character of the water coming down from above. Below this zone there is no movement of water, except through structural or thermal agencies, and the amount of water received from above is so small in proportion to that constantly present, and the waters coming down here themselves become so charged with salts and robbed of oxygen in their long journey through the rocks, that there is little chemical action. Below this level of no flow, structure and heat become determining factors in the distribution of ores. Above it, structure simply modifies general conditions, and heat is rarely an important factor in the problem.

At Dubuque the sea level lies some 500 feet below the lowest known workable deposit. There are no important modifying structural conditions, and the ores are found along the general line of the underground water level. The fact that within recent geological time this level has suffered important changes holds out the hope that the zone of ore accumulations will be found to be relatively deep.

It may be well to recapitulate here the reasons for believing that the dolomitization was accomplished before the deposition of the Maquoketa, and was not a wholly secondary change due to the ordinary circulation of underground waters. In the first place the dolomitization covers large areas and considerable thicknesses. It does not show any relation to definite fractures or water channels, but is characteristic of the whole extent of the formation. The rock is quite as completely dolomitized under cover as where exposed to the surface, and this is true even of the deeply buried portions of the formation, as Norton has shown from his studies of the artesian wells. Where dolomite has been definitely proven to be the result of changes brought about by circulating waters, it has shown definite relationship to water channels, joint planes, or other fractures and there is no such preponderating evidence in favor of such an origin for all dolomites as to throw the burden of proof upon those who would advocate another origin for any particular dolomite. Furthermore, if the change be referred to circulating water, it is incumbent to show the source of the magnesia which they must bring into the formation. A simple calculation based upon any of the analyses in the appended table will show that the amount of magnesia to be accounted for is very great indeed. The underground waters of the region in question as has already been shown, are, so far as the Galena formation is concerned, probably local in origin and in circulation. Granting the contrary, however, for the moment, and there are two possible sources; first, the Niagara, which is above, and second, the Oneota below. It is not certain that waters circulating through the rocks could be counted on to take up magnesia from the Niagara and carry it through the practically impervious Maquoketa only to redeposit it in the Galena. On the other hand, if the waters be held to have ascended it is pertinent to ask why dolomitization is limited downward everywhere by the shale with undolomitized limestone below? In either event such a solution of the problem would merely place the problem itself one step farther away and it would then be necessary to inquire as to the source of the magnesia in the Niagara and Oneota. It has been shown that there was no period of erosion between the Galena and the Maquoketa, so it is impossible to refer the change to surface waters of such a period.

The explanation suggested in the preceding pages has none of these difficulties to face and accords with all the known facts of the field. The absence of mechanical sediments in the Galena phase shows that erosion was not active, so that there were not large quantities of fresh water being poured into the sea to dilute it. The mere presence of the limestone shows that none the less deposition was taking place and there is reason to believe that this was shallow water deposition. The hypothesis of the change of the newly formed calcareous deposits to calcareo-magnesian deposits under the influence of overlying bodies of concentrated sea water accords perfectly with the known facts of the field and is not in discord with any. This with the inability of any other recognized process to explain the facts, has been the reason for its adoption.

PRACTICAL CONSIDERATIONS.

MINING TITLES.

Mining titles in the Dubuque region are, to some extent, clouded with the same uncertainties which are characteristic of titles in all new mining regions. The land has all been sold by the government and is held for residence or agricultural purposes. In general the mines are not worked by the land owners, but by lessees. In the past the leases have been largely oral agreements made in the presence of a witness, and were unlimited as to time. The rights of the lessee continued so long as the work is carried on in a "diligent and miner-like manner." In the absence of a clear definition of what "a diligent and miner-like manner" meant the courts have relied upon local custom, and this has been so uncertain that practically it has been a very difficult thing to dispossess a lessee so long as he left tools of any kind upon the ground. The net result is that many excellent leads are tied up in the hands of men who are not prepared to work them themselves, and who will not let others work them. The land owner, unless he has been exceptionally careful, is helpless, and in the absence of statute law the court decisions applicable are so few that rights are very poorly defined.

The exception is in the case of the land of the Bonson estate, or land leased under the Bonson rules. These rules, which were drawn up many years ago, cover many of the leases, and are given below:

RULES FOR THE GOVERNMENT OF LESSEES OF MINERAL LANDS OWNED BY THE BONSON ESTATE.

1st. Persons entering upon said lands to mine without the consent of the owner thereof, acquire no right therein by virtue of such entry.

2nd. Said lands are leased only by the range or crevice, and are to be worked regularly, continuously, and without cessation unless permission to the contrary be given by the owner thereof.

3rd. Lessees are not allowed to sell, convey or relet their working right in said lands without written consent of the owner thereof.

4th. Lessees are not allowed to remove, for the purpose of sale or otherwise, any mineral by them raised from off the ground by them occupied.

5th. Lessees shall sell no mineral by them raised to any person or persons without first notifying the lessor of such intended sale that he may be on the ground to protect his rights therein and collect his rent therefor.

6th. The lessee shall pay as rent to the lessor the one-sixth part of all mineral raised or mined from off the leased premises.

7th. A failure upon the part of any lessee or lessees to carry out any or all of the foregoing rules, shall work a forfeiture of all rights acquired in said lands, and the lessor shall have the right, without notice, to enter and take possession of the same; said lessee or lessees by their failure release any and all claims of whatsoever nature in and to the leased premises.

According to the sixth rule the royalty is fixed at one-sixth of all mineral, but mineral here is interpreted to mean lead ores only. At the time the rules were drawn up zinc was not mined. The customary royalty for zinc is 10 per cent. Since the introduction of concentrating works there is usually a provision that the cost of concentration shall be deducted before the royalty is paid.

METHODS OF WORK.

Up to 1899 there was not an incorporated company interested in the Dubuque mines. Up to the present the universal method of work had been by partnership. The mines are held as individual interests, and a system of Saturday night payments prevails. If ore has been sold, the proceeds are divided according to the various holdings. If no ore has been sold, an assessment is made to cover the deficit. The mines are small, but few men are employed, and usually the owners, or rather lease-holders, have little invested or to invest. Under such a system of working very little dead work is possible, as a mine which does not yield is simply dropped. It is impossible to enlist capital in an enterprise when the control is in the hands of men of no technical knowledge or skill, and of such slight business experience as in the case of most of the miners of the region. This, and the insecurity of titles mentioned above, have been the chief retarding influences. With such methods of business it is not surprising that ore has been poorly cleaned, has brought low prices, and that no serious attempt has been made to pump the mines so as to get at the lower ore horizons.

The system of working single crevices and depending upon single bunches of mineral to make a mine a success, must be abandoned if more money is to be invested in the region. The uncertainty of finding chimneys, and the large proportion of narrow work to stoping, make some modification of ordinary lode mining desirable. On the other hand the concentration of the ores along the crevices and at certain levels indicate that the methods of opening wide stopes followed in working the disseminated ores of southeastern Missouri, can not be followed entirely. It seems probable that the most successful mines will be located where crevices are known to be numerous and close together. The ground may then be worked as a whole by means of a deep pump shaft on the most favorably situated crevice, preferably near the center of the tract, and cross cuts driven along favoring north-south crevices at the level of some one of the various openings. Each main crevice can then be opened up by proper levels and uprises. Some of the area can be drained to advantage by levels driven in along certain well known crevices, but for reaching the lower horizons in much of the area, pumping will be necessary.

In the matter of pumping, little that is definite can now be stated. It is always difficult to judge the amount of water that must be handled in any mining operation, but in the present case there is no reason to believe the amount is excessive. Practically all the mining will be done above the level of the Mississippi, that is above the controlling water level of the region. There is no reason to believe that the mine waters are connected with the artesian aquifers below, as has already been shown. The presence of so much open ground, and the local difference in water level, indicate that the water is the ordinary underground supply, and, in a country so much cut up by streams and valleys as this, there is no reason to believe that the pumping will be more difficult than in other regions where water is now successfully handled.

PROSPECTING.

In seeking new country for development there is no better method than that of tracing out the known crevices. These have been so well opened up in the search for lead deposits that the general course is, in many cases, already known. The crevices are so definite in direction that it is quite feasible to survey ahead along the course of a well known crevice, and accurately locate a shaft upon it. Intersections are, of course, favorable points, and when two crevices can be traced to a crossing it is usually a good point to begin operations. Since the "openings," in so many cases, are actually open so that an explorer may crawl along them, and in other cases are filled with dirt carrying enough to pay for its removal, this is an exceptionally favorable region for prospecting by means of open shafts. The shafts of the region are small, ordinarily 3x5 feet in cross section, and are cheap, costing from $300 to $600. A single shaft may give access to a mile or more of underground openings. In such a case the shaft is pre-eminently the cheapest method of exploration. In many instances old shafts may be cleaned out at a cost of from 80 cents to $1.50 a foot in depth, in which case the exploration is even cheaper.

The fact that ore is distributed so irregularly along the crevices, a really valuable bunch of mineral occupying often a very small space, makes the drill less useful than it would be in locating disseminated deposits. Drilling has been very little attempted, and core drills have not been used in the region at all. It would be possible, of course, very quickly to settle by their use the question whether "flats" of value are to be found in the region, but they probably could not settle much of anything else. The question of flats will, in time, be settled in the course of ordinary mining operations in any event.

Recently power hoists and air drills have been introduced, pumps are being installed, and certain of the mines are being more systematically worked.

COMPOSITION AND TREATMENT OF ORES.

There are four general classes of ores at Dubuque, though these classes grade into each other to a greater or less extent. They are *a* lead ores, *b* dry bone ores, *c* mixed bone and jack ores, and *d* jack and pyritiferous jack ores. The lead, very rarely, occurs in any considerable amount so closely associated with zinc ore as to need to be separated by milling. Most of the lead is very pure and only needs to be washed free from the sand to be ready for charging in the furnace. In the general movement downard of the ores the lead has been concentrated in the upper and more weathered portions of the rock, which accounts for its relative freedom from impurity. It is a soft lead of nearly theoretical purity, specimens from the Karrick mine running 86.43 per cent Pb. It does not contain silver in more than a trace, though certain of the Illinois ores are said to yield enough silver to influence the price of the ore.

When lead occurs mixed with the other ores, as at the Ahern mine of the Dubuque Lead Mining company, where it, together with marcasite, filled solution cavities in a blue dolomite, and at the Pike's Peak mines where a certain amount of lead is found in intimate relations with the blende and marcasite, it is easily milled out owing to its greater specific gravity. This runs from 7.4 to 7.6, and in all milling operations the galena comes down on the screens of the first jig. Very little lead ore has, however, been jigged at Dubuque. It is generally washed with a log washer only.

The dry bone ores proper occur, as does the lead, in the upper weathered portions of the formation. They are usually hand sorted, washed with log washers, and hand picked. To a limited extent they are now being milled, and a considerable portion of the ore of the region can be marketed. Dry bone assumes a wide variety of forms from a clear translucent stalactitic variety, through honeycomb bone, to rock bone. Analyses of the ore from the Timber range or Ewing diggings have already been given. Assays of samples from the Cripple Creek mine gave 47.30 per cent Zn with 2.10 per cent Fe. The iron occurs as an oxide in the form of ocher or ocherous clay mixed with the ore. In washing the ore practically all the iron is gotten rid of.

The mixed bone and jack ores occur at and about water level. At present they are the ones most actively mined. Samples from the Alpine mine show 21.77 per cent, 21.6 per cent, 14.3 per cent of zinc with 9.88 per cent and 16.5 per cent of iron respectively in the last two samples. The iron here occurs in part as the sulphide and in part as the oxide. In milling it is impossible to separate the sulphide completely. In certain tested concentrates showing 47 per cent and 39 per cent of Zn respectively, 22 per cent and 19 per cent were in the form of the carbonate. By hand jigging a jack product showing 60.68 per cent metallic zinc, and a low grade dry bone showing 20.54 of zinc, were made. The proportion of jack to dry bone varies considerably in different mines, at different depths, and in different workings in the same mines. In much of the ore now being mined the bone and jack are in ratios of 3:1 to 4:1. The proportion of ore of all kinds to rock also varies considerably. Very little dead work has been done here, and the per cent of rock moved has been very small. The Alpine mine has been worked on about as extended a scale as any recent mine, and in the per cent of ore has run down as low as 12 per cent while cutting through bars. A mill run of ore from the Fourteenth street mine showed a trifle less than 16 per cent. The Bush and Langworthy ores run higher, but in neither case is any large ground opened up.

In milling these mixed ores it is impossible to make a complete separation of the bone and jack. Pure dry bone has a specific gravity of 4.30 to 4.45; pure blende runs from 3.9 to 4.1 In this field, however, much of the dry bone ore is really dolomite impregnated with zinc oxide. As a result there are all degrees from a dry bone heavier than blende to one lighter, and there must always be an important amount of middlings of mixed bone and blende. Such mixed ores are of lower value. On the one hand they are of lower value to the oxide manufacturer because the sulphur in the blende makes a sulphate in the oxide. The spelter manufacturer on the other hand loses a certain amount of the light bone in roasting the sulphur off the blende, since zinc volatilizes very easily.

The blende and blende-marcasite ores occur below water level, and are manifestly the ones which will be most mined in the future. The blende itself is an excellent smelting ore and quite free from iron. Its dark color appears to be due to organic matter and disappears at low heat. A selected sample of jack from the Rabbit Hollow mine showed 63.98 per cent zinc, with 42 per cent iron. Much of the ore, however, occurs with marcasite. Indeed it is usually true that between the dolomite and the blende there is at least a thin band of the iron sulphide. The iron sulphide seems to have caused the precipitation of the blende from the sulphate, with the consequent oxidation of the iron because of the weaker affinity of zinc for sulphur, as suggested by Van Hise. In milling it is quite difficult to separate the iron and zinc sulphides. Ordinary jigging is only partially successful. By roasting very slightly the iron sulphide can be made to swell up so as to be lighter than the blende, after which it can be jigged out as described by Blake.* By roasting heavily enough to drive the sulphur from both minerals it is also possible to use a magnetic separator. It is also possible to make a working separation by fine grinding and the use of concentrating tables, the Wilfly, Bartlett & Smith being seemingly best adapted to this particular class of ores.

While it is to be expected that, as more attention is paid to the district, better milling methods will be introduced, it is an open question whether the blende-marcasite ores can be in all cases successfully milled, and that fact is the most discouraging feature in the prospects for the district. At present the smelter, particularly where he makes sulphuric acid as a by-product, can do more than the mill man towards utilizing the ores.

The only mill now operating at Dubuque is a custom mill owned by the Dubuque Ore Concentrating Co. This mill has a capacity of from fifty to eighty tons in ten hours, depending on the character of the ores. The ores are run first through a 9x15 Blake crusher, then through 14x20 rolls, are elevated and sized by means of a trommel screen with one-half inch round holes. The over size from the screen goes to a second pair of rolls and back to the elevator. The undersize goes to a five-cell Cooley "rougher" jig, with 26x36 plungers, and 24x36 inch screens, which are grates with three-sixteenths inch holes. The eccentrics are driven at 140 revolutions per minute and have a stroke of $\frac{3}{8}$ to $\frac{3}{4}$ inch. The tailings here are hoisted and laundered away. The middlings are drawn and re-ground in a third set of rolls. This re-ground material, with the fine material passing through the screens, is re-elevated and run over a second, six-cell, "cleaner" jig, with plungers and screens 24x36 inches. The screens are 4, 6 and 8 mesh. The eccentrics of the first three plungers make 200

*Trans. Amer. Inst. Min. Eng.

revolutions per minute. The last three are driven 225 revolutions per minute. This plant uses about 400 gallons of water per minute, a part being caught in a pond and run through in a circuit. The power for such a plant is properly about forty-

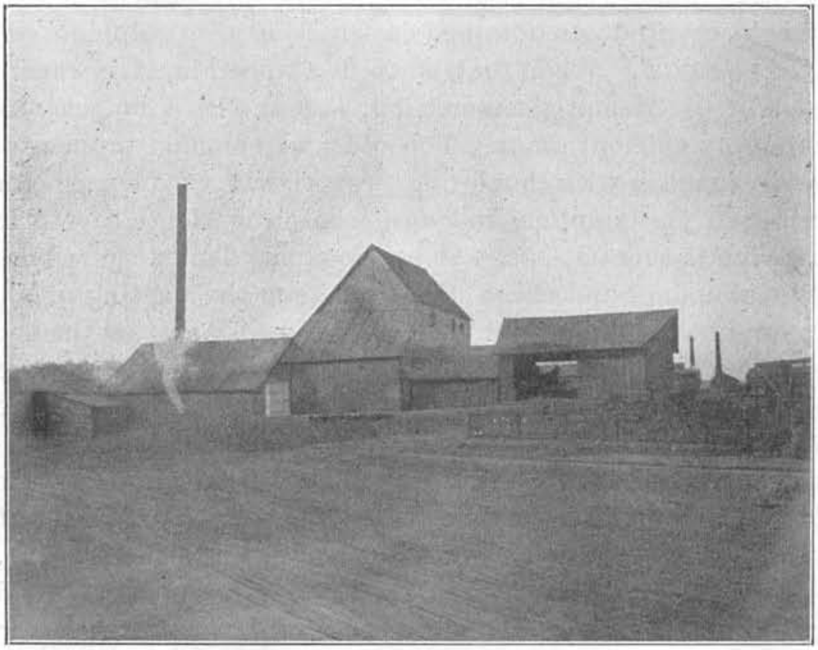


FIG. 95. Concentrating mill for lead and zinc ores. Dubuque Ore Concentrating Co., Dubuque, Iowa.

five horse power. In the Dubuque plant the engine and boilers are considerably in excess of this. In running, two men are required in the jig room, one in the engine room, and from two to three in the crusher.

SMELTING.

While both lead and zinc ores are mined in the Dubuque region, and iron has been mined within a few miles of the city, lead is the only mineral which has been smelted. The zinc ores are shipped to Mineral Point, Wis., and the various furnaces in Illinois and Indiana, and the iron, which was formerly shipped to some extent to Chicago, is not now worked. The reason for this lies mainly in the fact that it is possible to effect a good saving of lead by means of a furnace which requires but a very small investment, and which is accordingly within the reach of the local capitalists. Zinc, on the other hand, requires a considerable investment if the valuable by-products obtained in smelting the sulphide ore are to be saved. When fuel must be shipped in, it is rarely advisable to attempt zinc smelting, except with a modern and thoroughly efficient plant. The old and common process of spelter making with hand-rake reverberatory furnace for driving off the sulphur, and with coal-fired Belgian retorts for saving the metal, is not to be recommended except where coal is abundant and cheap, and even then the wasting of the sulphur entails a heavy loss. It is significant that in the Weir City, Pittsburg region, where so much of the Joplin ore has been smelted, these furnaces are being dismantled, while new ones are being erected in the natural gas region of Kansas. The building up of an important spelter industry in Indiana is indicative of the same conditions, and is but another instance of the well established rule that, in general, ores go to the fuel rather than the reverse. At La Salle and Peru, Ill., by means of finely equipped and excellently managed plants, it is possible to use coal as a fuel; but even here it is not used for direct firing, but is merely the source or producer of gas which, in an ingeniously devised furnace, is burned with very considerable efficiency.

The question as to the possibility of manufacturing spelter at a profit at Dubuque has not heretofore arisen for the reason that the blende has not been extensively mined. Very considerable bodies are, however, now being opened up, and the indications are that important blende mines will be a feature of the region from now on. With the opening of these mines and assurance of a considerable and steady supply of jack, the question of local spelter manufacture is bound to come up for consideration. There are now considerable bodies of blende open across the river in Wisconsin, and it is not impossible that, in the event of a local furnace being installed, these could be drawn upon to supply any deficiency of ore. Both Illinois and Iowa coals come into the Dubuque market, though the former commands most of the trade. Steam coal can be purchased there in car load lots at an average yearly price of $1.50 per ton in ordinary seasons, though now it is higher. The freight out on ore is now $1.50 a ton and upwards. These figures are sufficient to indicate that with a proper supply of ore assured, and a modern gas-burning furnace with arrangements for the saving of sulphuric acid, local spelter making is a potentiality of the future.

The zinc ores so far mined have been almost exclusively the carbonate. In the earlier days they were to some extent used for the manufacture of spelter, but are now exclusively made into oxide, to which they are particularly well adapted. The ores go to the Mineral Point Zinc company which has, at Mineral Point, Wis., the most important oxide plant in the west. The first attempt to smelt the zinc ores of the Upper Mississippi region was made by the Mattheison and Hegler company at La Salle, Ill., in 1852. Later the manufacture of oxide was taken up at Mineral Point under the direction of a certain Mr. George and Messrs. Jones Brothers, who visited Wales and spent sometime in the works there, learning the business. The company, after an uncertain and precarious existence of some years, is said to have formed a connection with the New Jersey Zinc company, and of recent years has been very successful. The original plant has been from time to time enlarged, and within the present season sulphuric acid works have been added. Forty thousand tons of zinc ore can now be handled per annum.

Zinc oxide is used as a base for white paint as a substitute for white lead. Its virtues are to some extent in dispute, white lead manufacturers declaring it a simple adulterant, but oxide burners and many painters stoutly maintain that it has a value of its own. It is claimed that it covers more surface than white lead in the ratio of 10:13, is not affected by sulphurous gases in the air and is not injurious to workmen. However that may be, it is largely used, 32,747 tons being manufactured and sold in 1898 with a value of $2,226,796. Oxide is preferably made from the carbonate ores for the reason that it is important that it should be free from all traces of sulphur. Mixed ores can be used to a limited extent and there is a certain market for oxide carrying not to exceed 4 per cent of sulphate. It is, however, better economy to use the sulphide ore for the manufacture of spelter and sulphuric acid and to depend upon the carbonate or "bone" for oxide.

Smithsonite or carbonate of zinc contains, when pure, one molecule of carbon dioxide and one of zinc oxide, or 35.19 per cent CO_2 and 64.81 per cent ZnO. In smelting it is necessary to get rid of the carbon dioxide. In order to do this it is necessary to heat the ore to almost 1,400° F., at which temperature the metallic zinc is reduced and volatilized, after which it is allowed to cool in the presence of an excess of oxygen, under which circumstances it is oxidized. In accomplishing this in American practice the ore is first crushed and cleaned if necessary, then mixed in about equal portions with anthracite coal in small sizes. Practically at the western works screenings from the city markets are used. This mixture of coal and ore is burned in a closed furnace over a plate grate punctured by small round holes which admit a powerful blast, but do not allow the particles of fuel and ore to drop through. The blast carries the metal and some unburned fuel over from the furnace into large fire brick settling rooms where all unburned particles settle to the floor and some of the zinc condenses, though the object is to make the condensation as little as possible. These rooms are subject to a periodical clean up when the settlings are reburned in the furnace. These rooms also secure a more thorough oxidation of the metals, as fresh air is admitted here. From the settling room a blast takes the vapors through a long iron cylinder designed to allow them to cool and to secure a thorough mixture of the air and the metal.

This cylinder or pipe leads to the bag room, an ingenious arrangement for saving the oxide. By means of suitable pipes and connections the blast carrying the oxide is turned into long canvas bags suspended bottom side up from the ceiling of the bag room. The air and gases, of course, find their way out through the meshes of the cloth, the cloth serving to catch the particles of oxide. The bags are in long parallel rows; at suitable intervals the blast is turned from one row into another, and the oxide is shaken loose from the bags. Beyond this point the process is the familiar one of barreling and marking.

The process is continuous and the works are only shut down for repairs or for lack of ore. It is, accordingly, necessary to carry a considerable stock of ore on hand. The plant is necessarily somewhat extensive and is expensive because of the large amount of fire brick used in its construction. Only the best and cleanest of fuel can be used, and this forms an important element in the cost of the plant. None the less it is believed that the industry has been, for some years, a well paying one.

The galena mined near Dubuque has always been smelted principally by local furnaces. A certain amount from counties north of Dubuque has been sold to the smelters at Aurora and Chicago, where it is usually in demand for mixing with the gold-silver ores of the west. Occasionally some of the galena has gone to the local furnaces of Illinois and Wisconsin.

The first attempt at smelting ore in the upper Mississippi region was made by Julien Dubuque, who, in 1788, opened up the mines where the city named after him now stands. He erected several furnaces in the region, and up to a recent time their sites were well marked. After his death the Indians destroyed his buildings, and, as far as possible, eradicated all signs of his occupation of the territory. The Dubuque mines were then for some years worked by the Indians themselves, who bartered the ore to a group of traders who had erected a furnace on one of the islands in the

Mississippi. In 1833 the country was opened to settlement, and since then smelting has been a regular occupation.

The pioneer furnaces of the region, and probably those used by Dubuque, were simple stone platforms approximately fifteen feet square, sloping toward the center. Upon these platforms layers of wood and ore were placed alternately and the whole was fired. From time to time more wood was added and the lead drawn off from the central well. The process was very wasteful, in that large quantities of wood were used and there was a very rich slag. Much of this old slag has since been gathered up and resmelted.

After some years a type of cupola furnace was introduced, and in 1834 Peter Lormier built the first in Iowa, locating it near the mouth of Catfish creek. Within the next two years two more were built, one on the Little Maquoketa and the other in the town of Dubuque. These furnaces are said to have saved from 65 to 70 per cent of the metal, but with the introduction of the Scotch hearth they passed out of use. It is said that the first Scotch hearth built in America was erected in 1835 about half way between Mineral Point and Dubuque. If this was really the first, Iowa can claim the second, as one was erected the next year near the southern limits of Dubuque. This furnace was later removed to just above Rockdale and re-erected on Catfish creek. It has played an important part in the mining history of the county, and is to-day still in operation, being operated by Mr. J. W. Waters, a grandson of the original owner. There were for a time two other furnaces in operation, Brunskill's, located near Center Grove, and Simpson's, northeast of Dubuque. For some years, however, the Waters furnace has been the only one in operation.

The Scotch hearth is a very simple and efficient furnace. Its general character, as used in the Dubuque region, is shown in figure 96. It consists essentially of a well in which the

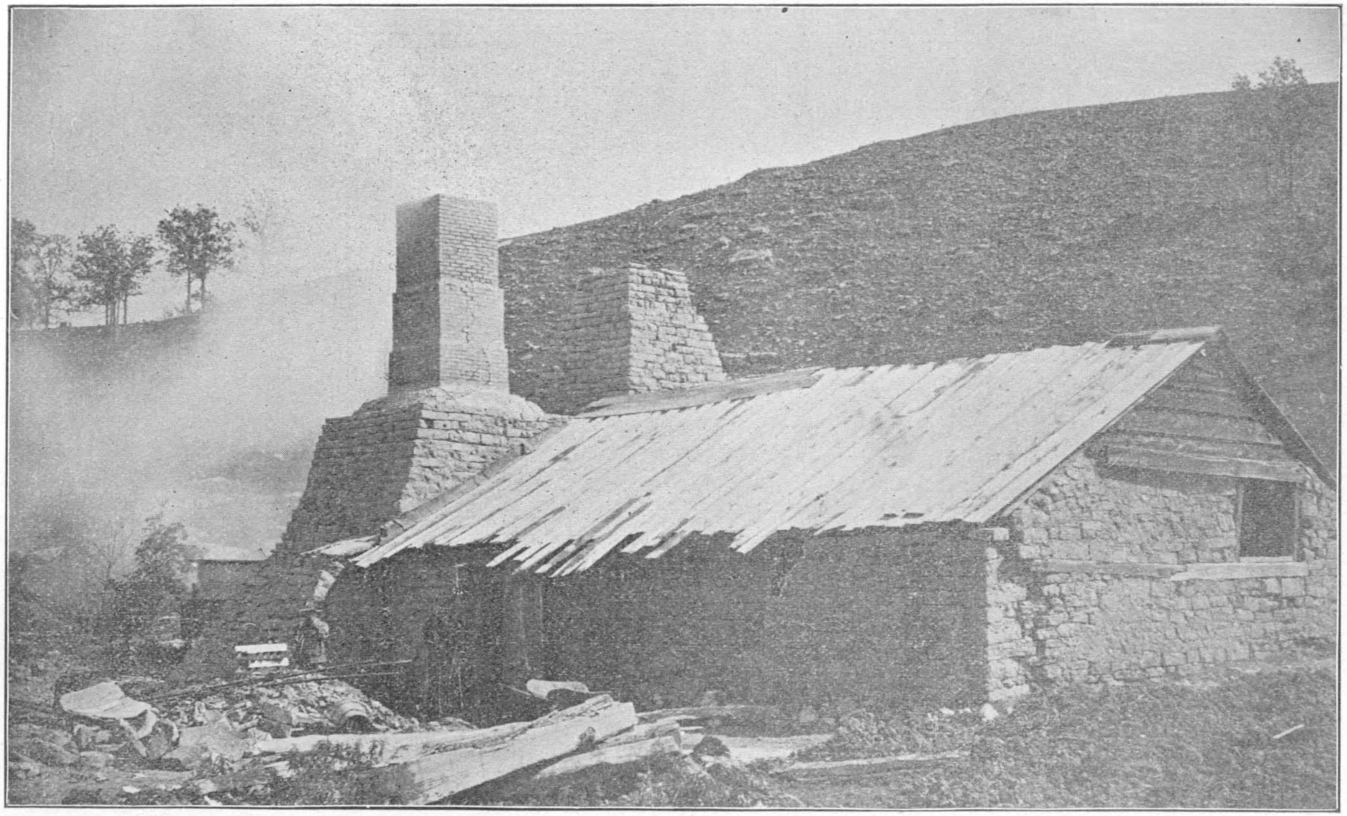


Plate XI. Waters furnace, Rockdale.

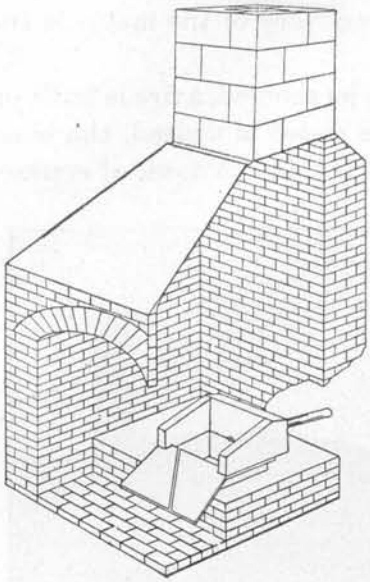


Fig. 96. Scotch hearth furnace as used at Dubuque.

metal is melted by means of a blast introduced from the rear. Ore and fuel are fed alternately, and the molten metal runs down over an apron into a mould. The box, or well, is 14 inches deep and 20x26 in area. It is made of cast iron $2\frac{1}{2}$ inches thick. This casting lasts twelve to fourteen years, and costs about $100. In improved forms it is hollow and cold water circulates through it, but here the solid casting is used and seems to answer the purpose. The blast is furnished by a blower now driven by an eight horse power engine, but it was formerly driven by water power. The smoke and fumes pass up through the over-hanging chimney.

A second hearth of a similar construction is used for re-running the slag from the first furnace. In running it coke is used, and the lead produced is slightly harder. The two hearths are run alternately, running sixteen hours and resting eight. About 1,700 pounds are run per day in each furnace. There are three shifts of men, each working eight hours, and they are paid by the number of pigs produced. Wood is used for fuel, and one-half cord is needed to reduce 300 pounds of ore, with two men and eight hours work. The hearth saves about 72 per cent of the lead. The fumes were formerly allowed to pass out of the chimney as waste, but the present manager has erected an ingenious arrangement for recovering them. They pass into a horizontal, sheet-iron cylinder, three feet in diameter and 100 feet long, and from that the smoke goes out of a second chimney twenty feet high. The lead settles in the horizontal pipe and the second chimney as fine dust, and is collected and re-run with the slag.

This gives a practically complete recovery of the metal in the ore.

In starting up the hearth after it has cooled, a fire is built on top and under the well. When the metal is melted, the blast is started and new ore and fuel are fed in. These, of course,

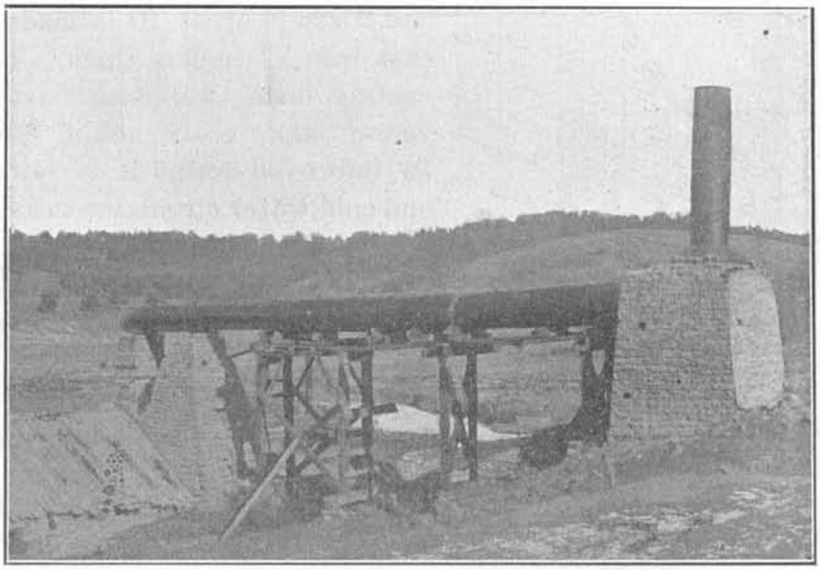


Fig. 97. Waters' lead furnace at Dubuque showing fume saving arrangement.

float on the surface of the molten metal, which in turn runs down into the mould. The metal is run in pigs of about seventy-two pounds weight, which are marketed locally, and in Chicago and St. Louis. The old furnace is shown in plate XI and the new fume saving arrangement is seen in figure 97.

The Scotch hearth lead furnace is an interesting example of the fact that in certain cases simple old fashioned processes are best adapted to local conditions. As the Waters furnace is now run, a more perfect saving is effected at less cost than would be possible in the most improved and modern high cost furnace. Yet the whole plant, including building and ore sheds could probably be duplicated for less than

$1,000. Where large capacity is, however, desired and a continuous supply of ore can be assured the cupola furnace is probably the better adapted to the work.

In conclusion the following analyses of slag after the first and second runs are interesting:

SLAG ANALYSES.

	First slag.	Second slag.
Moisture	.17	.05
Silica and insol	4.92	27.68
Ferric oxide Fe_2O_3	18.47	*29.60
Aluminium oxide Al_2O_3	11.86	7.04
Phosphoric pentoxid P_2O_5	1.52	.78
Manganese oxide MnO	2.49	1.94
Calcium oxide CaO	16.85	15.35
Magnesian oxide MgO	8.61	7.71
Sulphur trioxide SO_3	3.22	.37
Zinc sulphide ZnS	4.44	....
Lead sulphide	23.37	....
Lead (as metallic lead and as oxides)	4.48	9.48
Ferrous sulphide	....	29.60
	100.00	100.00

*As Fe_2O_3, FeO and Fe.

IRON.

In practically all the zinc and lead mines at Dubuque more or less ocher, or rust as it is familiarly called, occurs in the upper levels. In the lower levels a large amount of pyrites of iron occurs with the galena and blende. So important is the amount of pyrite that it is regularly shipped from certain of the Wisconsin mines. So far no attempt to dispose of it has been made in Iowa. The pyrite is an undesirable constituent in zinc ores, as both the iron and the sulphur must be taken out in the process of spelter making. It is not easily separated from the blende by any jigging, and serves in general to bring down the price of the zinc ore. If pyrite be found at any point sufficiently pure to be readily mined alone, it will of course prove valuable, as there is a ready sale for it to sulphuric acid manufactures.

The ocher found in the upper levels bears the same relation to the pyrite below that the dry bone does to the blende; that is, it is the oxidized or weathered equivalent of the pyrite. In the process of weathering the sulphur has disappeared, and the iron exists as an oxide, mixed with certain earthy materials, principally silica, resulting from the decay of the accompanying dolomite.

The normal unweathered dolomite of the region, the blue rock, contains from 1.5 per cent to 2.5 per cent of silica, with about .85 per cent of iron oxide and about 1.5 per cent of organic matter and water. In the brown or partially weathered rock these constituents assume the proportions 3.5 per cent to 5.5 per cent of silica and 1 per cent to 1.5 per cent of iron, while the organic matter is not notably increased. In the iron ores the silica remains about the same, the iron oxide runs up to 48 to 65 per cent and the organic matter and water increases to from 12 to 20 per cent. The change which has taken place is, in addition to the probable carbonization of the disseminated sulphide, the ordinary one of leaching out the soluble, and leaving the insoluble matter; and the large amount of organic matter and moisture found in the resulting ore indicates that the change has been accomplished by surface waters. It is the same change which results in the accumulation of cherts and the red sticky clay known as geest, in limestone countries long exposed to erosion. In the case of the iron ores, where the large bodies, as in this region, are surface deposits, or occur in caves or crevices directly open to surface, the action is plainly one of simple residual accumulation, and the ore may have been originally disseminated throughout any or all of the formations which formerly spread over the county and which have been cut out by the erosion. In the case of the zinc ores it has already been shown that the relations to the Galena limestone are probably closer.

While ocher occurs in practically all of the crevices of the region, and surface bodies of limonite are reported from several points, only one important body of ore has been developed. In the Levens crevice there is a large amount of ocher which would apparently be valuable for mineral paint, but which has not been exploited. The ore which has so far been marketed has come from the Larkum range near Durango. It occurs in an important east-west mineral crevice, and it was at first proposed to use the material for mineral paint. In the course of tests made in this connection it was recognized as a valuable iron ore, and a company, The Limonite Ore company, was organized to develop the property.

The officers of the company are Mr. W. S. Spangler of Chicago, president, and George S. Finney of the same place, secretary and treasurer. The company owns seven acres of land and has leases on 160 acres adjacent, the whole covering the mineral rights on the Durango iron mine. The mine is on the Chicago Great Western railway about a mile southwest of Durango on the Burton land, and includes a tunnel or drift 5x7 in cross sections along the vein some 1,200 feet. The ore can be dumped from the mouth of the drift directly into railway cars below. A certain amount of ore was mined in this tunnel by overhead stoping, but the main body lies a few hundred feet beyond the face and is as yet untouched. It can be reached through an old shaft 110 feet deep, sunk for lead ore; but during the course of the present survey there has been no opportunity to explore these old workings. They have, however, been examined by experts employed by the Illinois Steel company, and upon their report an offer was at one time made for the property. In 1896-97 about 250 tons of ore were shipped to the lake furnaces and used in furnace mixtures. The mine is 175 miles west of Chicago on a direct railway line, and the character of the ore is such as to make it fit for foundry iron as well as for ordinary furnace mixtures. It is open and porous and smelts easily. Its chemical composition is shown in the table of analyses given below and furnished by the company. In the absence of an opportunity to collect independently average samples, the survey has made no new tests of the ore. The analyses submitted are believed to be representative.

ANALYSES DURANGO IRON ORE.

	I.	II.	III.	IV.	V.	VI.	VII.
Fe	44.55	54.80	52.66	48.43	57.66	54.74	54.74
P	.247	.056	.142	.167	......	1.49	.249
SiO_2	7.25	6.04	5.25	5.99	......	4.50	4.50
H_2O	27.72	.88	14.00	......	......	13.65	......
Losonig	......	12.21	......	......	......	......	13.65
Al_2O_3 and Ti	......	.62	1.08	......	......	.88	.88
CaO	......	.55	.08	......	......	......	......
MgO	......	.15	......	.68	......	......	......
S	......	.06	......	......	......	......	......
MnO	......	......	.88	......	......	......	......
ZnO	......	......	......	......	......	......	.99

I. Illinois Steel company, analysis of four car lot, north works.
II. Washburn, Moen & Company.
III. Calumet Furnace company.
IV. Dickman & McKenzie.
V. Same, sample from east side of main shaft.
VI. Illinois Steel company.
VII. Illinois Steel company.

The value of an ore of any kind depends as much upon the cost of mining and the opportunity for smelting it as upon its character. It is difficult to give any estimate of the cost of mining in the present case, but apparently it would not be excessive. At present any ore mined would need to go to the lake furnaces, but the question of a local blast furnace is now being investigated. In addition to the Durango ores, such a furnace could draw supplies from the very large and easily mined limonite deposits now being opened up in Allamakee county. There is a good local market for pig iron, excellent transportation facilities both by rail and river, and a suitable dolomite for flux found in unlimited quantities. Below will be found analyses of the Allamakee ore and of the Dubuque dolomite:

ANALYSES: J. B. WEEMS, CHEMIST.

	Waukon iron.	Dubuque dolomite.
Water and loss	12.34	.15
Silica and insol	9.08	2.15
Iron oxide, Fe_2O_3	68.40	.82
Alumina, Al_2O_3	6.08	......
Manganese, MnO	.90	......
Phosphorus pentoxide, P_2O_5	.41	.60
Phosphorus	.18	......
Sulphur	.91	......
Sulphur trioxide, SO_3	.40	......
Undetermined	1.48	......
Lime, CaO	......	30.72
Magnesia, MgO	......	19.90
Carbon dioxide, CO_2	......	45.91
Total	100.00	100.25

LIME.

Dubuque is one of the most important lime-producing counties in the state. In 1898 it ranked third with a production valued at about $10,000 at the kilns. In former years the amount produced was much greater, but the recent increased use of Portland and natural cement has seriously affected the lime trade. There must always remain, however, a large amount of work for which good lime mortar is the best material. In work below water level it is, of course, necessary to use cements, but in walls exposed to the air, unless exceptional strength be required, a well made and well laid lime mortar is quite sufficient and must always be cheaper because of the simpler process by which it is manufactured.

There are two lime plants in Dubuque proper, the Eagle Point Lime works and the Key City Lime works. In White Water township there is a small intermittent kiln which at intervals burns a little lime.

The Eagle Point plant is large and well equipped. It is well located both as regards material and transportation, being at the point of the bluff where the river and the C., M. & St. P. railway are both available. The quarry face shows a thickness of about forty feet of rock which is used, the base being about fifty feet above the top of the Trenton. The detailed section at this point has already been given. The rock is a dolomite of sugary texture, massive and quite pure. The analysis shows 94.14 per cent of dolomite, the other constituents being as given below:

ANALYSES OF EAGLE POINT LIME ROCK. J. B. WEEMS, ANALYST.

	Lime-burning.	Non-lime-burning.
Water	.02	.04
Insol	2.15	8.63
CaO	30.72	28.86
Fe_2O_3	.82	.85
P_2O_5	.60	.57
MgO	19.90	18.82
CO_2	45.91	42.08
Organic	.13	1.07
Total	100.25	100.86

In connection with the analysis of the lime-burning rock an analysis is given of a non-lime-burning dolomite, which occurs in the quarry with a thickness of twenty-one feet. This rock does not make lime by ordinary methods, and the analysis shows that the high percentage of silica and alumina are the probable cause, the rock showing only 84.13 per cent of dolomite. The presence of the constituents indicate, however, that the rock might be used for natural cement, and certain tests made upon it by Professor Simms of the State University confirm this opinion.

In working the quarry the rock is blasted down, broken with sledges to pieces not more than six to eight inches in diameter, put in tram cars with drop bottoms, and run out over the kilns, whose tops are even with the quarry floor. These kilns are two in number, are continuous and are fifty-six feet deep. They are built of Galena limestone, the upper sixteen feet being 8x10 in cross-section, and the lower forty feet being oval, with a cross-section 6x7 feet. They are emptied by drop bottoms, and are fired by two fire boxes each, built into the sides of the kilns about six feet above their base. These boxes are five feet deep and are arranged to burn wood. It requires about four cords to burn 100 barrels of lime. The rock is burned in about sixteen hours, and the process is continuous, lime being drawn every six hours.

The lime is gray in color, almost as dark, in fact, as a cement. It slacks quickly with the usual swelling and evolu-

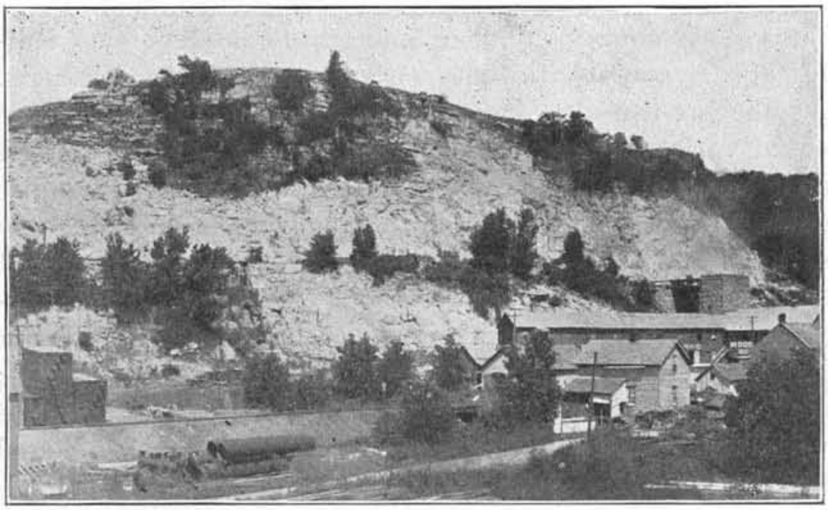


Fig. 98. Cliff of Galena limestone at Eagle Point Lime Works.

tion of heat. When slacked it is fairly white, but in use it makes a dark mortar. In making mortar $\frac{3}{4}$ yards of river sand are used to one barrel of lime. The barrels are supposed to contain 200 pounds, but are not weighed and they vary somewhat. In practice much of the lime is loaded loose into cars and shipped to large contractors in bulk.

Eagle Point lime is widely and favorably known. As is true of magnesian limes in general, it forms a very hard bond and makes a mortar which improves steadily with age to an undetermined point. The capacity of the plant is 120 barrels per day with each kiln. When running one kiln three men are needed in the quarry, with one fireman and one cooper. When both kilns are in use the force is increased.

The Key City Lime works on Eagle Point avenue use the rock immediately above the flint beds, about twenty feet of the section being taken. The trade is mainly local. The lime is burned with wood in three twenty-five foot kilns, drawing every five hours. These kilns have a capacity of thirty-five to forty barrels per day.

CLAYS.

The county contains a large amount of excellent clay suitable for manufacture into brick and other products. Nevertheless the clay industry is not a flourishing one, and both in variety and in quality the district is far behind its proper position. Excellent clays are widespread, and there are three formations from which they may be obtained. These are the Maquoketa shale, the loess and the alluvium. At present only the alluvium and loess are utilized. The abundance of good building rock and the prominence of the lumber industry have been, to some extent, responsible for this fact; but an important factor has been the presence at Dubuque of several hand yards using alluvium, burning with wood and manufacturing cheaply. Without the incentive of reducing costs or necessity from the nature of the clay for better appliances in order to make brick at all, there has been no sufficient motive for the introduction of machinery and consequent improvement in the quality of the output.

The brick now made are manufactured almost entirely by hand. They are sun dried and burned in ordinary cased kilns with wood at temperatures of about 1,925° F. In burning to an ordinary red brick, there is a shrinkage of about 12 per cent, of which more than one-half is in drying. In very hard burned brick the shrinkage amounts to as much as 15 or 20 per cent. The loess used at Dubuque is a sandy waterlaid type occurring at low levels. The high level loess, and the typical loess occurring along the Iowan border in the western portion of the county, have not been used. Loess of good character occurs within the limits of Dubuque city, and excellent dry press test brick have been made from it. It would seem that the conditions were favorable for a plant of this type, since there is good material, cheap fuel, easy transportation and an important local market. An attempt was made some few years since to introduce machinery and manufacture a high grade brick. This attempt proved a failure for business reasons rather than the nature of the material. It is rather surprising that nothing has been done in this line, since as early as 1857* repressed brick were manufactured here and used in the U. S. marine hospital at Galena. This repress was brought out from Philadelphia and was apparently one of the first used in the west.

For anything other than building brick it will be necessary to go to the Maquoketa shale for material. This formation is capable of yielding unlimited quantities of excellent material. From seventy to 150 feet of the section consists of soft very plastic clay. This forms the main portion of the Upper Maquoketa as elsewhere defined in this paper (p. 443). This clay is fine-grained and is eminently suitable for pottery; being in fact used for that purpose at Colesburg in the neighboring county of Delaware. Much of this section is available for the manufacture of shale brick, and will form an excellent hard burned brick. Specimens tested at Bucyrus, Ohio, show that when repressed, it makes a smooth cherry red brick of excellent strength and appearance. Possibly the material can be used for manufacture into pavers, though the relative large amount of lime in proportion to the other fluxes indicates that it would be difficult properly to control the temperature so as not to carry the process of vitrification beyond the desired incipient stage. It is quite probable that some of the shale would prove valuable for sewer pipe.

The use of the shale is limited by the rough topography which makes transportation difficult. There are, however, two points at which transportation is at hand, Kidder, on the

*Daily Express and Herald, June 6, 1857.

Chicago Great Western, and Peosta on the Illinois Central. At either point a good site could be obtained, though in each case the talus of Niagara limestone above would make the stripping tedious. An analysis of the shale as developed at Kidder is given below:

MAQUOKETA SHALE. J. B. WEEMS, ANALYST.

	PER CENT.
Silica SiO_2	42.53
Calcium oxide CaO	5.66
Magnesia MgO	4.82
Phosphorus pentoxide P_2O_5	00.00
Ferric oxide Fe_2O_3	5.66
Alumina Al_2O_3	16.83
Potash K_2O	3.70
Soda Na_2O	4.10
Combined water	15.76
Undetermined	.94
Total	100.00

BRICK PLANTS.

August Roeber has a hand yard on Rhomberg avenue, Dubuque. The clay is a loess, obtained on the bluff and carted down to the yard, which is situated on the Wisconsin terrace. It is pugged in pits by horse power, made up by hand, sun-dried, and burned in case kilns. Wood is used in burning, with three to four days of water smoking, and a total burn of seven to eight days. Segers cones show that the temperature of burning is between 1,922° Fahrenheit and 1,938° Fahrenheit, or .05 and .04 of the cone series. The clay burns to a dull salmon red with very little warping. In drying there is a shrinkage by volume of 16.19 per cent and a total shrinkage of 20 per cent. The final brick are $8\frac{1}{4}$x$3\frac{7}{8}$x$2\frac{1}{8}$. The principal market is local, though a certain amount of brick is shipped.

Deitreich Brothers operate, on Lincoln avenue, a plant similar to that just described. The clay here is hauled down, soaked over night and then pugged and made up as before. It burns in eight days with a wood fire and shrinks 11.18 per cent in burning to ordinary hardness, and 14.68 per cent in hard burning. The finished brick are $8x2\frac{1}{8}x3\frac{7}{8}$ in size.

The D. Meggenberg yard is located on Broadway extended. In this case the loess occurs on the ground, and the pit shows a face of about ten feet, of which the upper half is dark-brown above becoming lighter below. The lower portion shows parallel horizontal bandings and is a light buff color and sandy texture. In work about one-third of the upper clay is mixed with two-thirds of the lower. In drying the brick they are laid flat for six hours and then ricked up.

The Albert Gasser yard is located on Grandview avenue, near the crossing of Dodge street. The loess is here found on the premises and made up as usual, except that instead of being moulded by hand, a horse power machine is used. This resembles the ordinary pug except that moulds are placed in it and by a lever motion the clay is pressed down, filling the mould. This mould is then pushed out in front and an empty one put in its place. The mould which is filled, is hit a slight blow to loosen the clay, and is then dumped on the yard. The moulds are washed in water and sanded before being put in the machine. By this plan some 10,000 brick are made per man, while by hand only about 8,000 are made. It is claimed, too, that the brick are stronger.

John Heim owns two yards. The smaller is a hand plant located near the Gasser yard just described. The larger yard is just off Couler avenue near the Millville road. At this yard the usual loess clay, soaked twenty-four hours, is made up by machine. It is delivered from the pit to a carrier which drops it into the pug mill. The latter is twelve feet long and is the Monarch type. The clay is moulded in wooden moulds, sanded automatically, and similar to those used at the hand yards. The brick are sun dried and burned in cased kilns at a temperature of about 1,900° Fahrenheit, with a wood fire. The plant includes a twenty-five horse power engine and has a daily capacity of 30,000 brick.

The Kidder brickyard is located on the bottom-land at Kidder crossing, on the Chicago Great Western. Alluvial clay is made up by hand and burned in cased kilns over a wood fire with the usual results.

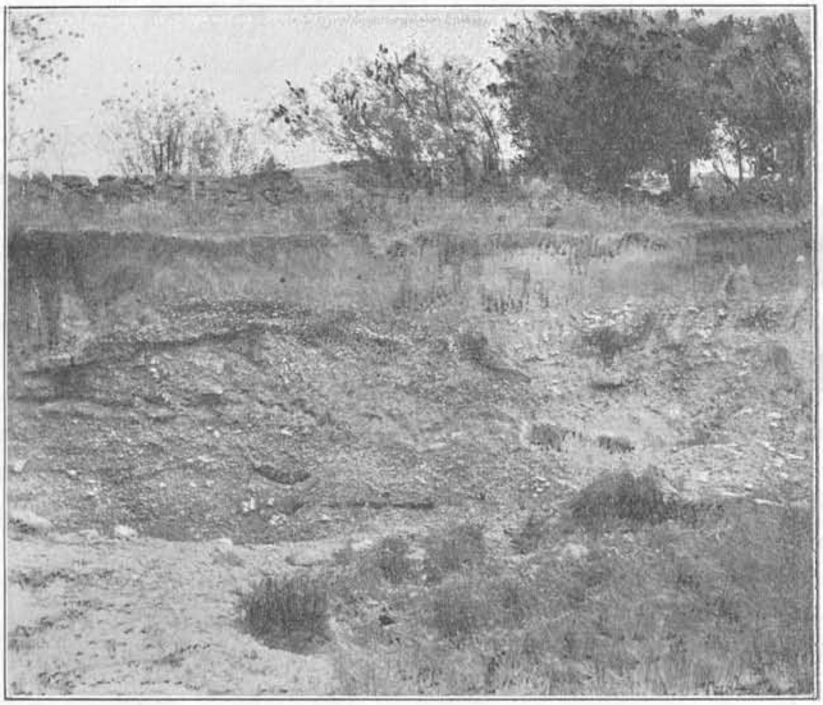
PIGMENTS.

Within the county there are a number of materials which enter into the composition of modern paints. A large amount of the zinc ore sold from the region is used in the manufacture of zinc oxide; the lead may be so used, though it is here reduced to the metallic form. The Durango iron was first exploited as a pigment, and there are in many of the mines considerable quantities of ocher, which has in some instances yielded good experimental results. Barytes, which is used as an adulterant in white lead, occurs, though it has not as yet been found in quantity. There is an abundance of flint or chert both in Niagara and Galena. This material is suitable, after fine grinding, for use in mixed paints to give them body. Probably the most hopeful field for development is the ocher, which occurs abundantly, may be cheaply mined, and is adapted for use in producing the common darker reds.

ROAD MATERIALS.

The rough topography of the driftless area and the drift border region has made it necessary that more attention should be paid to roads here than is common in Iowa. As a result the county has many miles of excellent roads, and affords an example of what might readily be done with profit in many other portions of the state. The dolomite and limestone occurring so abundantly throughout the county have been chiefly used. These are hand-broken and then spread and rolled on a graded and hard rolled surface. A top dressing of gravel or finer crushed rock and loam make an excellent finishing material. In Dubuque city about 10,000 cubic yards of crushed rock are used yearly for repairs and extensions.

The gravels of the Wisconsin terrace and the Buchanan gravels of Kansan age afford a second important source of road metal. Gravel is used especially in the western portion of the county where rock outcrops are rarer and stone is accordingly higher in price.



F.G. 99. Residual cherts on Catfish creek, available for road material.

A third source which is capable of yielding large amounts of excellent material is found in the flint beds. The chert beds of the Niagara, especially, yield a very large amount of flint of sizes suitable for road use with very little additional work. This material is often washed out and concentrated along the streams flowing down from the Niagara escarpment, so that it needs only to be screened to free it from clay to be used. Sections of such gravels, two to twelve feet in thickness, may be found along Catfish and Granger creeks. Flint is much harder than limerock and will accordingly wear much longer. The macadam made from limestone cuts into ruts very quickly and requires frequent repairs. The flint macadam does not cut so readily; but it does not, when flint is used alone, pack so firmly, and in order to get the best results it is necessary to make the road more carefully and to use a good top dressing, preferably of some ferruginous material.

BUILDING STONES.

Dubuque county is abundantly supplied with a good grade of building stone. The Galena-Trenton and the Niagara are each capable of furnishing moderate and high grade dolomites over a wide area. The large portion of the area which is driftless, and the consequent broken topography render quarry sites abundant. While there is as yet very little stone shipped out of the county, local needs are well supplied, and an increasing trade is being built up. There are four quarry horizons in the county, all yielding dolomitic rock, though the character of the rock from each is somewhat distinctive. The non-dolomitic portion of the Trenton and the Maquoketa yield practically no rock of value in building operations. The stratigraphic position, geographic distribution and general character of the different quarry beds have already been discussed (pp. 417-459) and it is sufficient here to recapitulate.

The lowest quarry horizon of importance is found in the Lower Buff beds of the Trenton. These beds are exposed only along the Mississippi and at the mouths of immediately adjacent streams in the general neighborhood of Specht Ferry. As so situated they have the advantage of transportation at hand, in the C., M. & St. P. railway and the river, but they are not usually accessible by wagon route. Being situated at or near the base of the river bluff they are rarely uncovered enough to be accessible and open to quarrying. The rock itself is of good character. It is a firm, hard, coarse textured dolomite cut by vertical joints and occurring in ledges varying in thickness from eight to ten inches to three feet. In general the horizon is characterized by a tendency toward thick ledges and massiveness. Practically it is not available except at the angles between the Mississippi and tributary streams where narrow tongues of rock are free from heavy stripping. The horizon includes from ten to twenty-five feet

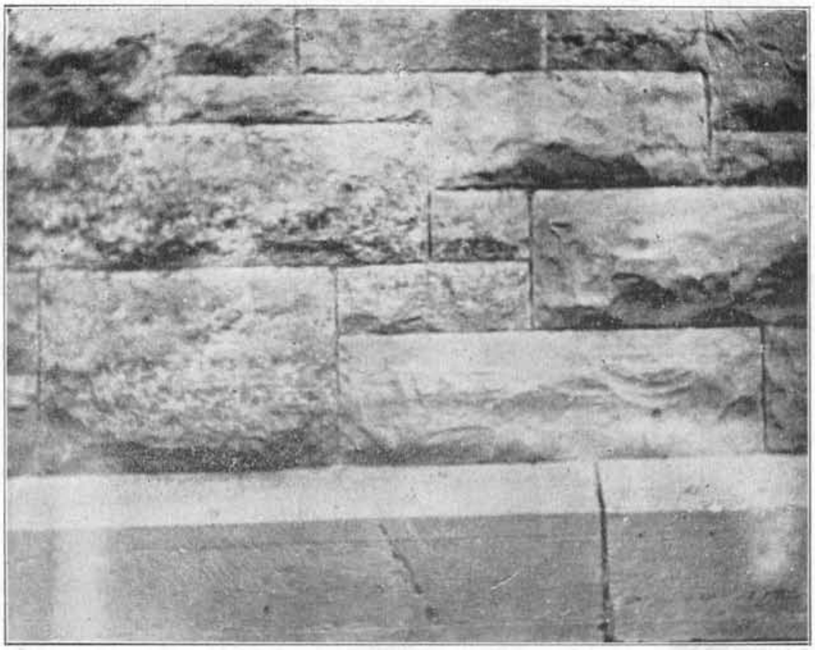


FIG. 100. Use of Galena dolomite in massive construction.

of suitable rock. It is opened up on the C., M. & St. P. railway about three-fourths of a mile below Specht Ferry and in section 10 of Peru township.

The second important quarry horizon includes the upper portion of the Galena formation, Nos. twelve to fourteen inclusive of the general section (p. 423). This horizon includes from seventy to ninety feet of rock which at various points is more or less quarried. Practically operations are confined to the upper fifty feet. The rock is thin-bedded above, ranging from four to ten inches and separated by thin shaly interlaminations. It becomes more massive below running into beds four feet and more in thickness. In the earlier operations the thinner, more easily quarried beds above were mainly used, but of recent years more reliance has been placed in the heavier bedded layers below. The rock is hard, completely dolomitized, granular in texture and rough and carious on exposed faces. It does not make a good appearance in dressed stone work but is excellent for ashlar, rough dimension work and coarse masonry. In bridge work, foundations and lower courses in large buildings it makes an excellent appearance. It is used best where the effect of rugged, massive simplicity and strength are desired, but it looks cumbersome in other situations. The stone has high crushing strength and good lasting qualities, but its transverse strength is relatively low. It very rarely shows horizontal laminations or bandings of any kind but is as massive in appearance as granite. This stone has not heretofore been appreciated at its true value, but the Chicago Great Western railway has for several years been using it in their improvement work with excellent effect, and in Dubuque proper, enough has been laid to show its capabilities.

Below the horizon indicated there is a considerable thickness of rock which is more or less quarried for concrete, lime and road material, but less rarely for building stone. Much of it could be used to advantage, though the presence of chert in some portions, and the heavy, massive character of other layers making them difficult to dress, except by machinery, throw them out of competition, for the present, with the more easily quarried beds of the upper horizons.

The leading quarries working on the Galena limestone are located on the Chicago Great Western railway between Graf and Twin Springs, and in Dubuque on Dodge and South Dodge streets, Eighth street, Fourteenth street, and at the crossing of the North Cascade road and the Illinois Central railway. The first named quarry belongs to Mr. T. H. Houston. The beds quarried begin about ten feet below the top of the Galena proper, and the base of the quarry is forty-five feet below. The stone is in ledges varying from four inches to two and one-half feet, most of it being one foot or more in thickness. It is buff, coarse grained and carious. It is worked by simple hand drills and plug and feather work, with an occasional blast. Horse power cranes are used in han-

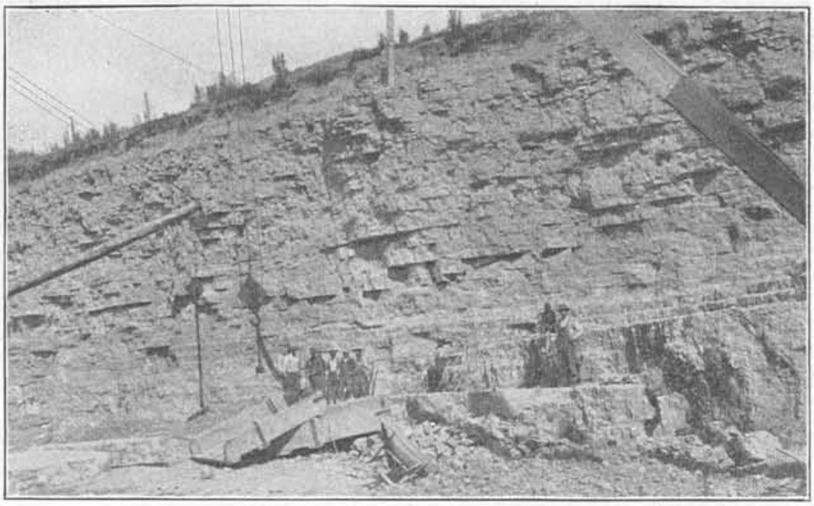


Fig. 101. Upper part of Galena limestone, Houston quarry, on Chicago Great Western railway, near Graf.

dling it. The stripping is about ten to twelve feet in thickness and consists of weathered rock which is used for riprap. The quarry produces about seven cars of stone a day, with a working force of eleven men and three boys.

The Dodge street quarries are three in number and include the Tibey, Burns & Saul, and the Jas. Rowan. They show faces of about thirty-five to forty feet, including a portion of the upper thin beds and of the better rock below. These upper beds yield six and eight inch stone, but are not now marketed extensively, and the stone is not of as good quality as that below. The lower beds yield ten to sixteen inch rock, with some running twenty-four and thirty-two inches. In the quarries is the so-called "cap rock," which is normally found immediately above the upper openings in mining operations, and is about four feet thick. It caps or splits in quarrying, and its massiveness is more apparent than real.

The Eighth street quarry is now worked only for macadam as is true also of quarries on Couler avenue at the foot of Diagonal street, on Broadway and Diagonal, at the end of

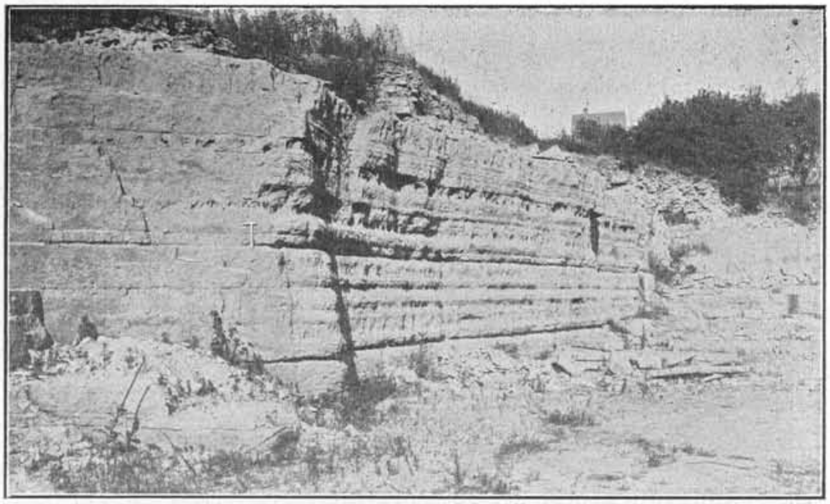


Fig. 102. Galena limestone, Dodson quarry.

Southern avenue, and elsewhere. The Chris Voelker quarry on Wood street and the numerous small quarries near Fourteenth street yield some building stone. The Wm. Dodson quarry on the north Cascade road shows a face about 400 feet long of the beds above and including the cap rock. Throughout the city, and indeed the area of outcrop of the Galena, there are numerous other openings which from time to time are worked for stone.

The Niagara includes two important quarry horizons; the lower and upper quarry beds. The former is immediately above the basal beds, which are fifteen feet thick, and below the chert. It includes about twenty feet of good stone, is worked to advantage in the Farley quarry but has not been opened up very extensively in other parts of the county. The chert breaks down, forming a talus, which readily hides the quarry beds, and this is probably one reason why they have been quite generally overlooked. At the north Farley quarry belonging to B. N. Arquitt and located on the Chicago Great Western railway, the stone is sawed and dressed by machine. The plant includes one gangsaw capable of handling rock 6x12 feet, and rubbing bed twelve feet in diameter. The stone tools very easily and in appearance is not unlike the famous Anamosa stone. Figure 52 shows the lower quarry stone as it appears in the east Farley quarries.

At about 165 feet above the lower quarry beds are the upper beds, which have also a normal thickness of about twenty feet. They are opened up at many points but the main quarries are near Cascade. These quarries have already been described. (See page 452).

The Niagara quarry stone, as distinguished from the Galena, is very much finer grained, is usually lighter in color and shows notable laminations. It is a magnesian limestone rather than a dolomite, and occurs in thinner beds. It is better adapted to cut stone work than the Galena, but is not so good for the heavier work. It makes a very pretty wall when laid in broken ashlar with trimmings of whiter dressed stone, as shown by St. Martin's church at Cascade.

ARTESIAN WELLS.

In the course of a general study of the artesian wells of the state Prof, W. H. Norton visited Dubuque and made detailed investigations of the numerous wells which supply such an important amount of water in the city. His notes of the subject are so complete that they are reproduced below.*

*Iowa Geol. Surv., Vol. VI, pp. 208-214.
Since the investigation made by him the water company has drilled new wells and now draws its supply entirely from them.

DUBUQUE ARTESIAN WELLS.

(BY W. H. NORTON.)

	Depth.	Bore—inches.	Elevation of curb, A. T.	Original head.	Present head, A. T.	When finished.	Original flow in gallons per minute.	Present flow in gallons per minute.	Casing.	Water horizons, A. T.	Driller.
1. Linwood cemetery.	1,954	3	706	742	707?	1891	40	20	1,025	-297 to 943	1
2. Linwood cemetery.	1.765	......	776‡	753‡	......	......	......	......	......	......	..
3. Water Works Co...	1,310	10	607	653	......	1888	2,500?	......	400	107 to-703	1
4. Butchers' Associa'n	1,000	5	707	740	648	1887	580	......	......	......	1
5. Malting Co.........	999	5	634	......	......	1895	......	......	......	......	2
6. E. Hemmi, dairy...	973	......	627	......	......	1895?	......	......	......	......	1
7. Bank & Ins. Bldg Co	973	4½	638	648	648	1894	120	120	150	73 and below.	1
8. J. Cushing, factory	965	5	642	673	642	18[illegible]8	......	......	......	42 and below.	1
9. Packing & Pro. Co.	955	6	607	662	688	1889	340	......	200	......	1
10. Lorimer house.....	1,057	5	652	709	652‡	......	400	0	......	......	..
11. Schmidt brewery...	886	6	630	......	645	1891	......	......	80	130 and below.	2
12. Steam Heating Co..	802	4	617	704	617‡	1894	260	0	......	264, 1,378-163.	1
13. Julien house.......	896	4	615	724	712	......	480	......	222	......	1

1. J. P. Miller & Co.
2. J. Bicksler.

Dubuque probably ranks first among the towns of the state in the output of artesian waters, and is outclassed only by Davenport in the number of its flowing wells.

The first artesian water, so far as reported, springs from the New Richmond horizon of the Oneota at 264 A. T. The second supply mentioned is in the Jordan sandstone from 137 to 107 A. T. Water is reported also from the upper part of the Basal sandstone from 262 to 326 feet below tide, and from 544 to 944 feet below tide. Below the latter depth the Basal sandstone was found to be dry.

The original head of the wells 1,000 feet deep or less seems to have reached from 700 to 740 A. T. In the deeper wells in Linwood cemetery the water rose a few feet higher, perhaps to 753 A. T. In several wells there has been a notable loss of pressure. How far this is due to exhaustion of the local basin is hard to say. In several instances the loss is largely attributable to other causes. After 1887 no well less than 1,000 feet deep headed higher, so far as we know, than 673

‡Approximately.

feet A. T. The head of the well drilled in 1894 at the Bank and Insurance building was only at 648 A. T., about the height of the present heads of the other wells of the class except that of the Julien house. If the water of the latter well still rises to the reported height, 712 A. T., it would show that no serious overdraft on the basin has yet been felt. Unfortunately no report of pressures on the new wells of the Malting Co. and Mr. Hemmi's can be obtained from their owners. While it is very probable that the less deep wells have been multiplied beyond the capacity of the local supply, we find little reason to believe that the lower reservoirs from 514 to 944 feet below tide have been overdrawn.

The following analyses show the exceptionally high quality of the artesian waters of Dubuque:

	GRAINS PER UNITED STATES GALLON.				
	No 1.	No. 2.	No. 3.	No. 4.	No. 5.
Calcium carbonate	7.471	7.2379	9.4559	7.5881	8.096
Magnesium carbonate	3.794	4.4186	4.3775	6.3623	7.179
Calcium sulphate		2.1830	1.2841		
Magnesium sulphate				0.2918	
Sodium sulphate				0.9607	
Potassium sulphate					1.582
Sodium chloride	2.568	2.0488	1.6927	0.3502	0.204
Magnesium chloride	1.926				
Alumina and Ferric oxide					0.035
Silica					0.872
Total	20.429	19.2621	20.4295	15.6432	17.968

No. 1. Malting company's well, from 200 to 300 feet. Analysts, Wahl and Henius. Authority, Schmidt Brothers.

No. 2. Malting company, at 900 feet. Analysts, Wahl and Henius. Authority, Schmidt Brothers.

No. 3. Malting company, at 999 feet. Analysts, Wahl and Henius. Authority, Schmidt Brothers.

No. 4. Cushing's well. Analysts, Wahl and Henius. Authority, James Cushing and Son.

No. 5. Steam Heating company. Analysts and authority, C. F. Chandler.

DUBUQUE BANK AND INSURANCE BUILDING COMPANY.

	GRAINS PER U. S. GALLON.	PARTS PER MILLION.
Silica (SiO_2)	.298	5.143
Alumina Al_2O_3) and Ferric Oxide (Fe_2O_3)	.646	11.143
Lime (CaO)	4.118	74.000
Magnesia (MgO)	2.378	41.000
	GRAINS PER U. S. GALLON.	PARTS PER MILLION.
Potash (K_2O)	......	.....
Soda (Na_2O)	1.665	28.714
Chlorine (Cl)	Trace	Trace
Sulphur trioxide (SO_3)	.996	17.143
Carbon dioxide (CO_2)	11.658	201.000
Water in combination (H_2O).	2.129	36.714
UNITED AS FOLLOWS.		
Calcium bicarbonate (CaH_2) ($(CO_3)_2$)	9.587	165.287
Calcium carbonate ($CaCO_3$)	1.434	24.714
Magnesium bicarbonate (MgH_2 $(CO_3)_2$)	8.625	148.714
Sodium carbonate (Na_2CO_3)	1.533	26.428
Sodium sulphate (Na_2SO_4)	1.765	30.428
Alumina (Al_2O_3) and oxide of iron	.646	11.143
Silica (SiO_2)	.298	5.143
Solids	23.888	411.857

Analyst, Dr. J. B. Weems. Date, May 30, 1896.

Several engineers report that the water corrodes iron pipes and makes some scale. The deeper waters of the Linwood cemetery wells are said to be poor as drinking water. Sanitary analyses of artesian waters have seldom been asked for, and the following of the well of the Bank & Insurance Building company, by E. W. Rockwood, is of interest as showing the high organic purity of waters of this class:

	PARTS PER MILLION.
Total solids	277.000
Loss o1 ignition (no charring or odor)	62.000
Free ammonia	.016
Albuminoid ammonia	.006
Chlorine	......
Nitrates	......
Nitrites	......
Sediment	......

Color none, odor none, taste good.

Equally significant is a bacterial analysis made by Dr. G. Minges, of Dubuque, of the water of the artesian well of the water company, in which he found but twenty bacteria to the cubic centimeter.

The artesian wells contribute but a portion of the water furnished by the water company. A large amount of excellent water is furnished by an abandoned tunnel in the bluff, two and one-half miles from the city, one mile in length and about 100 feet below the surface, which was once used to drain mines. A third supply is obtained at Eagle Point, 500 feet from the bank of the Mississippi, from 300 drive wells from thirty to sixty feet deep. The impression prevails that this supply is derived from the river by filtration through its banks of sand. This is not the case. The water is common surface or ground water, and its contamination is shown by a bacterial analysis by Dr. Minges, who found as high as 5,290 bacteria to the centimeter in water taken directly from this pumping station. Under these conditions the advice given of late years by some physicians of the town to consumers to boil all drinking water has not been untimely.

Belonging to the same local basin is the town well at East Dubuque, from which 750,000 gallons are pumped daily. The well is 983 feet deep, bore six inches, and registers a pressure of thirteen pounds. One hundred feet of red shale, the Saint Lawrence, were reported as lying near the bottom of the boring.

A curious fluctuation has been noticed in the well of James Cushing & Son, the discharge sometimes being much more than at others. In the deeper well at Linwood cemetery the tubing is sometimes obstructed by a "fibrous sediment," probably crenothrix. The removal of this by churning an iron rod in the tube has doubled the diminished flow.

*For the facts relating to the wells at Dubuque, we are under obligations to H. S. Hetherington, who donated a tube of samples from the Steam Heating company's well; to Dr. W. Watson, Mr. Jas. Beach, and to several owners of the wells. Mr. W. H. Knowlton, city engineer, kindly supplies the elevations of the curbs, except that of No. 2, Linwood cemetery, which is estimated by one of our correspondents.

RECORD OF STRATA.

Driller's log of Steam Heating Co.'s well:

		THICKNESS.	DEPTH.
15.	(Alluvium) "depth to rock"	165	165
14.	"Sandstone"	6	171
13.	"Sand and shale"	5	176
12.	"Limestone, white"	128	304
11.	"Limestone, gray"	42	346
10.	"Sand and lime" (inspection of the tube shows that this includes a cherty limestone, perhaps arenaceous, a gray limestone and lowest a brown, cherty, arenaceous limestone)	135	481
9.	"Sandstone," brown	20	501
8.	"Marl," yellow	3	504
7.	"Sand and lime"	10	514
6.	"Sandstone"	62	576
5.	"Lime"	18	594
4.	"Marl, red"	87	681
3.	"Shale, sandy," green	64	745
2.	"Marl, red"	10	755
1.	"Sandstone" cream yellow	48	803

DESCRIPTION OF DRILLINGS OF SCHMIDT'S BREWERY WELL.

		DEPTH OF SAMPLE.
25.	Sand and gravel	25
24.	Sand, yellow	30
23.	Sand, reddish	56
22.	Dolomite, buff, aspect of Galena, samples at 60 and 65 feet	60 and 65
21.	Limestone, dark bluish-gray and buff	80
20.	Limestone, magnesian, or dolomite, dark drab, mottled with lighter color, in small angular fragments, residue after solution large, argillaceous, siliceous and pyritiferous, three samples	100 to 114
19.	Sandstone, white, moderately coarse, grains rounded smooth, and comparatively uniform in size	126
18.	Dolomite, light yellow gray, nearly white, with much sand in drillings	140
17.	Sandstone, as No. 19	156
16.	Dolomite, drillings chiefly chert	189
15.	Dolomite, gray, highly cherty at 250 from	210 to 250
14.	Sandstone, white, many grains faceted, some dolomite chips in drillings	254
13.	Dolomite, light buff, in fine sand, with chert and quartz sand	258
12.	Sandstone, white, with calcareous cement	267
11.	Unknown, no samples or record	...
10.	Dolomite, buff, cherty	426

9. Dolomite, brown, chippings splintery, mostly of flint with some of drusy quartz........................ 430
8. Sandstone, cream yellow, moderately fine, calciferous as shown by dolomitic and cherty material in drillings, three samples......................465 to 474
7. Dolomite, buff in fine sand, with some quartz sand.. 478
6. Sandstone, light reddish-yellow, fine, calciferous... 535
5. Dolomite, in fine buff sand and gray chips.....581 to 584½
4. Shale, highly arenaceous, glauconiferous, in chips which pulverize into reddish-yellow powder (at 632 feet) and reddish-brown (at 636 feet), quartzose matter microscopic and angular..............632–636
3. Dolomite, highly arenaceous, glauconiferous, in fine brown angular sand at 724 and in coarser sand at 726..724–726
2. Sandstone, yellow, grains moderately fine, the larger rounded and smoothed............................ 730
1. Sandstone, pure, white, grains rounded, moderately fine.. 841

DRILLER'S LOG OF JULIEN HOUSE WELL.

		THICKNESS.	DEPTH.
10.	Depth to rock	210	210
9.	Sandstone	160	370
8.	Marl	66	436
7.	Sand, marl and lime mixed	50	486
6.	Sandstone	60	546
5.	Limestone	105	651
4.	Marl, red	40	691
3.	Shale, sandy	46	737
2.	Marl, red	7	744
1.	Sandstone	141	885

SUMMARY.

The wells of the lower town pierce the alluvial deposits which fill a preglacial or interglacial channel of the Mississippi river. The elevation of the fluvial floor of rock at the Steam Heating company's well is 452 feet A. T., and at the Julien house, 405 feet A. T. if the record can be trusted. Schmidt's brewery stands near the cliffs of the present gorge and here rock lies at 570 feet A. T.

The record of the Julien house well falls in with the other records only in part, but the samples of the Schmidt well are in close agreement with the record of the Steam Heating company. Combining these data we have the following section:

	THICKNESS.	BASE A. T.
Galena	.....	550
Trenton	46	504
Saint Peter	58	446
Oneota	310	136
Jordan	95	41
Saint Lawrence	179	-138
Basal sandstone	1,110	-1,248

CEMENT.

Between the Galena and Maquoketa there are certain transition beds normally about twenty feet thick. These are yellow in color, uniform in texture and composition and grind easily. They contain 83.50 per cent of calcium and magnesium carbonates about equal in proportion and are well adapted as regards character to the manufacture of cement. They also can be found in favorable situations as regards transportation facilities. As has already been noted certain of the layers in the quarry of the Eagle Point lime works are also suitable for cement manufacture. It would, however, be impossible to make a Portland out of either of these rocks and in the present conditions of the trade there is no encouragement for new plants for the manufacture of the cheaper natural cement.

The Trenton, as will be suggested by the analyses given, is a non-magnesian rock and when it occurs in favorable situation as regards transportation and clay, might well be used for making Portland. Some excellent samples have been collected and tested but so far no body of the rock has been found sufficiently free from magnesia and sufficiently extensive and uniform, to warrant investment. Possibly more detailed studies over the whole Trenton area would bring to light one or more such situations. In appearance and character the rock is very much like that of the Lehigh region which is so extensively used in cement work.

FORESTRY NOTES FOR DUBUQUE COUNTY.

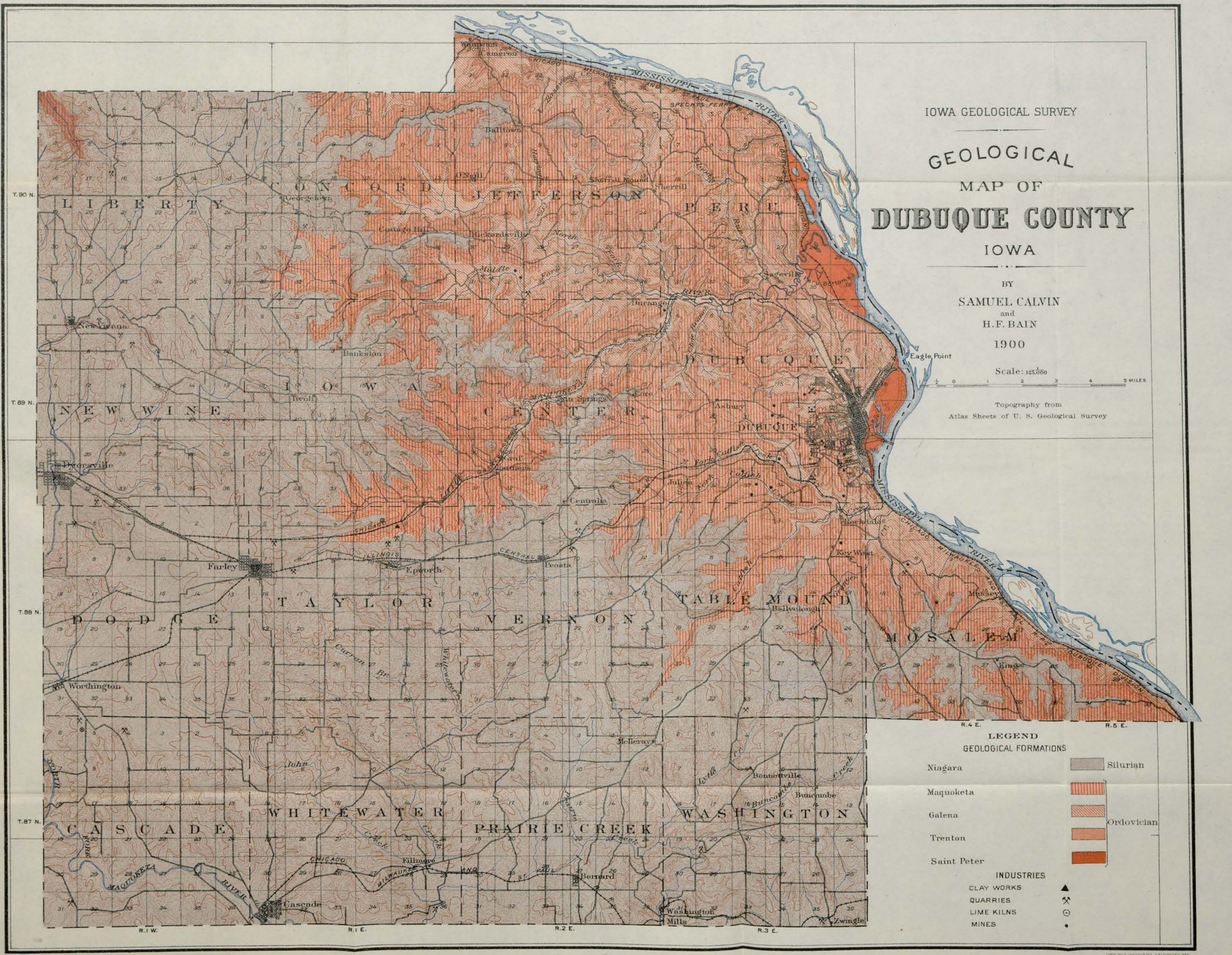
BY THOMAS H. MACBRIDE.

Dubuque county is one of the so-called "river counties" of the state of Iowa. The primeval forest of the county, accordingly, formed a part of that narrow isthmus of woodland, which, following the banks of the Mississippi river, connected the great forest areas of the north and south, of Minnesota and Missouri. The narrowness of this belt may be inferred when we reflect that in Iowa at least it nowhere involved the width of a single county. Its westward extensions, too, were narrow, almost uniformly confined to the banks and valleys of streams tributary to the greater river. Dubuque county, perhaps even better than any other, affords an excellent illustration of the general situation. Though one of the best wooded regions of the state many of its townships were chiefly treeless prairie. Liberty, New Wine, Dodge, Vernon and Prairie Creek, though not wholly without forest, were yet called prairie townships, while Taylor, Washington, White Water and even Julien, by the very banks of the river, were prairie in proportions by no means small. Groves of great white oaks marked the ridges of yellow clay or loess, similar clusters of bur oak crowned the rocky hills of the driftless area, while bur oak and black jack vied with each other, generally to the disadvantage of the former, in an effort to occupy the poorer soils where erosion had spread out the sands and gravels of the drift. Only in the protected gorges of the driftless regions and along the steep bluffs facing the

Mississippi, typical forest conditions prevailed and trees in greatest variety found foothold and flourished.

On the advent of civilization the checking of prairie fires gave the forest here, as elsewhere, great relief. Young trees came up in every direction, partly from seeds, partly from so-called bench-grubs, old stump-like stocks which had been in the days of prairie fires again and again burned off, only to start again in shoots and suckers with the advent of spring; but destined so long as the fires swept over them, never to attain tree-like dimensions. These bench-grubs sometimes were very old and possessed an extensive root system. This accounts in part for the rapidity with which the forests of Iowa began to spread with the arrival of civilized men. In the case before us the early farmers selected, of course, the more level country; the steeper and poorer hills were left to nature and became quickly forested, covered with what is called second-growth, an assemblage of trees denser and darker than ever occur in nature under any other circumstances. In Julien and Peru townships some of these second-growth forests may yet be seen which have been growing at least fifty or sixty years. So that the oft-repeated remark as to the number of Iowa trees, to the effect that their number has greatly increased since the country has been settled, is strictly true.

In these later years, however, the rapid increase in land-values has changed entirely the forest situation in Dubuque county as everywhere else in the state. The second-growth is being rapidly cleared away and the surviving trees of the old forest, the great white oaks and bur oaks, have been hurried to the sawmill to make cheap lumber for all manner of domestic use. Every foot of land on which the plough may be made to pass is coveted for agriculture, and the forest as a whole is doomed. Fine bodies of second-growth are still to be seen, to be sure, but their respite is due not to any policy of forest preservation—the average farmer knows nothing about such a thing—but simply to the fact that time


IOWA GEOLOGICAL SURVEY
GEOLOGICAL
MAP OF
DUBUQUE COUNTY
IOWA
BY
SAMUEL CALVIN
and
H.F. BAIN
1900
Scale: 1/125,000
0 1 2 3 4 5 MILES
Topography from
Atlas Sheets of U. S. Geological Survey
LEGEND
GEOLOGICAL FORMATIONS
Niagara
Silurian
Maquoketa
Galena
Trenton
Saint Peter
Ordovician
INDUSTRIES
CLAY WORKS
QUARRIES
LIME KILNS
MINES
LIBERTY
CONCORD
JEFFERSON
PERU
IOWA
NEW WINE
CENTER
DUBUQUE
DODGE
TAYLOR
VERNON
TABLE MOUND
MOSALEM
CASCADE
WHITEWATER
PRAIRIE CREEK
WASHINGTON
T. 90 N.
T. 89 N.
T. 88 N.
T. 87 N.
R. 1 W.
R. 1 E.
R. 2 E.
R. 3 E.
R. 4 E.
R. 5 E.
MISSISSIPPI RIVER
Eagle Point
Dubuque
Farley
Epworth
Peosta
Cascade
Worthington
Dyersville
New Vienna
Balltown
Georgetown
Durango
Centralia
Fillmore
Bernard
Zwingle
Bennettville
Buncombe
Key West
Rockdale
Massey
Ballyclough
Asbury
Sherrill
Sageville
Cottage Hill
Rickardsville
Bankston
Washington Mills
Melleray
Graf
Sherrill Mound
Tivoli

and strength have not as yet availed to effect the clearing. Even the rocky heights and gorges of the driftless region are being rapidly denuded, as anyone may observe who passes on the train down the valley of historic Catfish creek, and, on plea of securing blue-grass pasture, all the natural covering of these rougher portions of the country is rapidly disappearing, leaving for the most part bare limestone rocks and walls to bleach and burn in the summer sun. In such ill-advised agriculture the loss to the farmer is three-fold; he loses his trees, which if properly cared for might have furnished his holding, generation after generation, with a most convenient source of supply for posts, fuel, and wood to meet all sorts of needs upon the farm; he loses his land, for no sooner have the stumps rotted than in many places the soil begins to wash and blow away, so that fields may be shown to-day where there is nothing but rock; he loses often lower-lying good land which is destroyed by the wash spread out from the cleared hilltops. Nay, the loss is greater still; the farmer who thus strips the gorges and rocky hillsides of their forests withdraws permanently what ought to be his contribution to the maintenance of his county's water-supply as represented in springs and streams. Take the woods from Pine Hollow, for instance, and forthwith every stream will go dry, every fountain vanish. Fountains and streams go with woods. They are habitually so associated in speech, in all literature, and the result of forest-removal as affecting the water-courses of a country is perfectly well understood. Not only do the streams, uncovered by forest shades, dry up in summer, but, what is worse, they become in spring and winter rushing, ungovernable torrents, destroying all fields and meadows wherever they go. Every man who comes to us from Austria, France, or Switzerland knows the truth of this statement; but we need by no means go so far for illustration; the farmers of Dubuque and Delaware counties may see the situation for themselves as they drive along the highways. All the experiences of older nations and people confirm those conclusions in this matter which are suggested by our daily observations upon our own farms, to the effect that the extirpation of native forest is the worst sort of political economy, and that the highest type of agriculture is impossible where the forest has not its allotted place and where trees are no longer allowed to perform their beneficent work.

But there is still another side to this question as presented by the situation in the county before us. The time has passed, if ever it existed, when the welfare of the county was measured wholly by the records of the freight conductor. The homes of men are something better than even granaries and barns. The great number of our farmers realize that the farm should be beautiful as well as productive, especially when productiveness and beauty are entirely compatible and consistent with each other. Farm values in Dubuque county are reckoned in accordance with the "improvements" carried. If these improvements are attractive the farm is salable at high price; if unattractive, the farm is proportionately cheap. Now nothing shows more natural beauty on a piece of land than a grove of trees, especially if it shade rocks and running water. The farmers of Dubuque county have wonderful opportunity in this direction. Nature has been extremely generous. Whereas men of the prairie counties must perforce plant and cultivate their groves and every tree that shall shelter or decorate their holdings, the happier husbandmen of Dubuque find almost everywhere trees and groves as part of nature's gift. They have only to preserve what nature offers to show landscapes fair as those of old Luxemburg, Austria or Bavaria. On the other hand nothing is more unsightly than the bare cliffs and rocks of Niagara or Galena limestone, nothing as absolutely unproductive. The rocky hills and bluffs of Dubuque county, once they are entirely denuded of their woods, their natural covering, will present a scene of desolation entirely out of harmony with the name and fame of Iowa.

Further than this our problem reaches. For, where the timber holdings of the farmers are grouped together we get the effect of a public park. After what has been said it is hardly necessary here to say that no county in the state offers for public resort more beautiful or attractive natural facilities. The wooded bluffs about Dubuque should be made a common where those delightful shades and majestic scenes and views might be for the perpetual enjoyment of all the people. As this is written comes the word that a movement is already on foot to do something of this sort. Mr. Stout's gift to the city of a considerable tract of park land is a beginning and should at least serve to call attention to the wonderful park possibilities which form the magnificent suburbs to the old Key City of this state.

But is there any reason why even a public park should be the adjunct and property of the city only? People, especially in Iowa, do not all, by any means, live in cities. The several country towns or townships of Dubuque county may also use and enjoy the gentle and humane iufluence of the well-kept field of nature. The great forests of the old world are free to the poorest comer, and the people enjoy their glories and are happy. These parks are not in the cities always; they are forest reserves on the hills and mountains, and by the rivers and streams. No people can so cheaply enjoy such parks as can the people of eastern Iowa. In Dubuque county the people of Liberty, New Wine, and Concord townships, have at hand in Pine Hollow, a park, the gift of nature, which centuries of human effort might hardly produce. Here are deep shade s rocky walls, trees and shrubs of every species indigenous to the soil, bubbling springs, with abundant waters—what can we ask for more? Pine Hollow is to-day but a series of wood-lots owned by a hundred farmers. All it needs is judicious management, the building of a few bridges, with roads and paths and the communities of New Wine, Luxemburg, and Georgetown would have the most delightful park in northern Iowa. The region should belong to a corporation, to an association of the parishes, say, immediately adjoining. As the wood-lots, one by one, are offered for sale, they should be purchased by the corporation, or parish even, that the forest as a whole be not destroyed piece-meal by thoughtless individual owners. If the whole valley were under one control the destruction caused by "wood-rats," timber-thieves, would be greatly lessened, if not entirely stopped, since means could be easily adopted to effectually exclude all depredators and trespassers.

But, it will be asked, what can be done for those sections of this county which, through thoughtlessness, have been exposed already to the destruction of the elements? What shall we do with that dry ravine, that rocky hilltop? that barren cliff? It was once wooded; now it produces nothing and mars the beauty of the farm; can it be redeemed? Of course, the only hope lies in replanting, reforestation. We must remember that nature has spent ages in bringing about the condition of affairs which we have disturbed, and such is the peculiarity of our Iowa climate, that the re-establishment of wooded conditions anywhere with all our pains and skill is likely to be a matter of much difficulty. But it is feasible; it can be done. By means of planted groves forest conditions have been set up in central Kansas, and the same thing can therefore much more hopefully be attempted here, where the rainfall is so much greater. Trees in the places referred to are not likely to come up of themselves. Here and there, in time, such might be the case; but we must not wait for this. A tree plantation must be established, protected summer and winter from the ravages of cattle, cared for as any other crop, if success is to be made sure.

One of the far-reaching plans inaugurated by the present United States Commissioner of Forestry, provides intelligent and efficient assistance, without cost, to any and every farmer who desires to redeem, by tree planting, the waste lands of his demesne, or holding, and land owners are invited to correspond with the Secretary of Agriculture at Washington on this most important matter.

In any event Dubuque county offers for experiment in this reform one of the most favorable regions of the state, and it is hoped that the intelligence and patriotism of her farmers may soon find expression in the restoration and preservation of her beautiful groves and forests, not alone by the establishment of public parks, but in the maintenance of smaller groves and thickets, covering the rocks and sands, and giving to the county a landscape beauty and charm difficult to rival. When we begin replanting, a list of such woody plants as are or were indigenous to the region becomes in a high degree a thing of practical value. Such a list here follows.

It will be observed that the list of woody plants for Dubuque county is almost identical with that made out in these reports by Mr. Cameron for Delaware county.* Clayton county will probably yield a similar list which may again be compared with that of Allamakee county.† All these counties share in the driftless area of the state and exhibit the richer variety of forest species which that peculiar region seems everywhere to afford. In fact so characteristic is the flora of the area in question, as found in Iowa, at least, that the presence of certain species in any locality is sufficient to raise the inference at once that the station has never been visited by the drift. The White pine, *Pinus strobus* L., is not known native in Iowa except in driftless regions, or in their immediate vicinity. The same is true of the Paper birch, *Betula papyrifera* Marsh., the Witch-hazel, *Hammamelis virginiana* L., besides a number of herbaceous plants rare to our flora. A most interesting problem touching the relationship of present vegetation to the present geologic changes is suggested by these peculiarities in distribution, but we are not as yet in possession of sufficient data to warrant generalization.

*Rep. Iowa Geol. Surv., Vol. VIII, pp. 193-9.
†Rep. Iowa Geol. Surv., Vol. IV, pp. 112-120.

The season or period of drought through which Iowa has for several years prior to 1899 been passing has left its mark in the forests as elsewhere. In the second-growth woods of Dubuque county there are to-day thousands of dead trees, dead of drought.

This must not be reckoned an occasion of special alarm. It is simply nature's method of thinning her forests. In any systematic treatment of a forest plantation trees are continually removed. They must be, in order that individuals of the various kinds and species may attain characteristic perfection. Nature thins by removing in a dry seasons the weaker, the less advantageously placed, the over-shadowed and over-crowded.

This is an illustration in a broad way of what naturalists sometimes call the "survival of the fittest." Of course the survival while preserving in the long run the fittest for the great and far-reaching purposes of nature may not result to our convenience at all. We may see our oaks and hickories dying in numbers while aspen-trees, locusts, willows and elms remain. The wise farmer will take heed to such a situation, removing in time the less valuable species and so establishing year by year a forest of oak or hickory.

In short, the time has come in Iowa and throughout the northern states when forestry, the cultivation of trees in forests, is to be a matter not of shelter and ornament only but of profit, and those who earliest realize the situation will soonest find the reward of their wisdom and foresight.

The list of woody plants and trees in Dubuque county is as follows:*

*For much aid in preparing this list the author makes acknowledgment to Miss Emma R. McGee, of Farley, Iowa, and to Prof. Jno. A. Anderson, of Dubuque.

ANGIOSPERMÆ.

Dicotyledones.

TILIACEÆ.

Tilia americana Linn. Basswood. Linden. American Linden. This is a beautiful, rapid-growing tree, growing best in rich soils, but thriving on rocky hillsides, especially along water courses. One of our finest shade trees, growing well when transplanted to the loess, or clay hills, and certain to be of greatest use in reforestation. The wood is soft, of little use as fuel but yielding a light easily worked lumber useful in construction of furniture, machinery, and even in interior finish of houses. Common; but large trees have been mostly cut out.

RUTACEÆ.

Xanthoxylon americanum Mill. Prickly Ash. A common shrub, along streams; liable to form thickets several acres in extent. This is a very pleasing ornamental shrub and grows well even in dry soils. The flowers are of two kinds, sterile and fertile, appearing before the leaves and on different plants. The reddish berries are very pretty in fall, but to secure the production of these in any case, shrubs of the two sorts, that is those having the fertile and those having sterile flowers, must be planted near each other.

CELASTRACEÆ.

Celastrus scandens Linn. Climbing Bittersweet. Bittersweet. Not infrequent on wooded hillsides, in thickets and by hedge rows. Climbing by coiling about the stems of shrubs or small trees, it sometimes overspreads and suffocates its support; sometimes chokes the stem by the closeness of its coils. Its bright red berries in fall are brilliant decorations of the woodland and, as the vine is easily transplanted, it should have a prominent place in the adornment of home grounds and farms.

Euonymus atropurpureus Jacq. Wahoo. Waahoo. Burning Bush. An elegant shrub, sometimes reaching a height of fifteen feet, rather rare everywhere, but still found along streams on rocky banks, as of the Mississippi bluffs, in Pine creek hollow, etc. Another valuable ornamental tree. Its curious four-parted purple flowers are part of the glory of June, and the no less remarkable, lobate, scarlet fruit, likewise contributes not a little to the beauty of our autumn.

RHAMNACEÆ.

Ceanothus americanus Linn. Jersey Tea. Common on half wooded prairie hills, and even out on the prairie, but more frequently at the thicket edge or near the bur oak clump. Formerly abundant in Dubuque county. A perennial with hard, woody, reddish roots, whence sometimes called red root, bearing very pretty white clusters of flowers from the shoots of the season. Well worthy of a place on every lawn.

Rhamnus lanceolata Purrsh. Buck-thorn. Prof. Hnderson reports this common in certain localities. It is common over the eastern part of the state wherever there is forest.

VITACEÆ.

Vitis cordifolia Michx. Wild Grape. Frost Grape. So called, because in this latitude the fruit is palatable only after a pretty severe frost. This is the common wild grape of the Mississippi valley. It flourishes in all wooded or semi-wooded regions, covers the rocks and binds the thickets; its bloom lends the most delicate perfume of spring, and its fruit in fall, now eagerly sought by flocks of south-moving birds, was once prime part of the store and treasure of the pioneer. Wild grapes when thoroughly ripe possess a most delicate flavor, and, under the manipulations of the skillful housewife, are said to be unequaled for the manufacture of conserves and jellies.

Ampelopsis quinquefolia Michx. Woodbine. Virginia Creeper. Five-leaved Ivy. American Ivy. An exceedingly common woody-vine in all parts of the county; in the woods and by the hedge-rows or fence-rows on the prairie farms. Commonly cultivated as an arbor or porch plant, for which purpose in our climate there is nothing better. The fruit is in autumn purple, resembling somewhat the looser clusters of small grapes. The very best plant in the world to cover the bare rocks of this county, and all sorts of denuded cliffs and crags.

SAPINDACEÆ.

Acer dasycarpum Ehrh. Soft Maple. White Maple; or even sometimes called Silver Maple. Common on river and creek bottoms everywhere. Perhaps more commonly planted in Dubuque county, and indeed in all eastern Iowa, than any other tree. The rich alluvial soils along the streams form the favorite habitat, and a splendid grove of these trees now stands near the mouth of Maquoketa creek in Peru township. soft maples make rapid growth, furnish an excellent quality of fuel, and yield to the cabinet and furniture-maker a useful Soft white lumber. Recent authors in forestry write this species down as *Acer saccharinum* Linn.

Acer saccharinum Wang. Sugar Maple. Rock Maple. Hard Maple. Once a very common tree throughout the county; now represented chiefly by small trees in the so-called "second growth." Along the face of the Mississippi river bluffs, and on rocky banks in all limestone regions. Of the primeval woods, some few large trees still survive in Pine Hollow. A tree of comparatively slow growth, but of surpassing excellence. As a shade tree its dense foliage is unequaled; for fuel there is no better wood, while the lumberman prizes hard maple lumber among his choicest products. The trees of this species do not well bear transplanting from the forest. True, they seem to flourish for years, but they do not by any means reach the normal size and sooner or later die at the top and perish, perhaps fifteen or twenty years after planting. Trees from the seed do much better. One difficulty, no doubt, is the fact that transplanted trees are set singly or in rows. The hard maple is above all a forest tree and flourishes in forest conditions only. Single trees in Iowa succumb to drought. By observing such precautions as will make our efforts conform to the known habit of the species, there is no reason why maple orchards may not again stand in Iowa, as they have been more than once renewed in New England and New York.

By some recent writers this species is called *Acer saccharum* Marshall.

Acer spicatum Lamarck. Mountain Maple. Moose Maple. This is a shrubby species tending to form thickets. It never attains the stature of a tree. It is immediately recognized by the circumstance that its flower-clusters are erect, spicate racemes, appearing *after* the leaves. Valuable as an ornamental shrub. Doubtfully referred to Dubuque county, but to be looked for on the steep sides of the bluffs facing the Mississippi river.

Negundo aceroides Moench. Box Elder. This is another species exceedingly common in cultivation. Everywhere planted for shade and shelter, and for both purposes excellent. Valuable also as a nurse for trees of other species, that is, to be planted as a temporary protection to more valuable species. Miss McGee reports the box elder native along the Maquoketa river in Cascade township, and the species was no doubt indigenous in all parts of the county. It starts very rapidly from the seeds in all sorts of localities.

This should probably be called *Acer negundo* Linn, and for common name, Ash-leaved Maple is in some places preferred.

Staphylea trifolia Linn. Bladder-nut. A shrub six to ten feet high, common in all the wooded parts of the county. Valuable as an ornamental plant. It blooms early and remains long in flower, the whole tree being for a time a mass of blossoms, not especially showy, but very beautiful withal. The bush well deserves a place in every dooryard but should be planted where it can have plenty of room, as it tends to sprout from the roots and will make a thicket. In late summer the twigs are hung with curious, three-sided, whitish, inflated pods in which the nut-like seeds lie loosely, whence the popular name.

ANACARDIACEÆ.

Rhus typhina Linn. Velvet Sumac. Staghorn Sumac. Eastern Sumac. Common in all the northern part of Dubuque county and probably extending along the Mississippi river southwards. A most beautiful shrub or small tree. Specimens six inches in diameter and twenty feet high occur along the bluffs. On high rocky ground everywhere. Valuable only as an ornamental plant, for which purpose it is, among native species, unexcelled. The brown velvety branches, the profuse delicate foliage, the crimson clusters of pilose berries, make a series of attractions that should commend the velvet sumac to every lover of the beautiful.

Linne is said to have given to this plant an earlier name, *Datisca hirta*, and recent authors write *Rhus hirta* (Linn.) Sudworth.

Rhus glabra Linn. Sumac. Common Sumac. Smooth Sumac. Everywhere throughout the county. Only a little less desirable as an ornamental shrub than the species last mentioned. Should be planted as a screen, or to border or fringe the grove, where in autumn its scarlet foliage lends an inexpressible cheer to the fading landscape.

Rhus toxicodendron Linn. Poison Ivy. Poison Oak. Poison Sumac. Common everywhere and exceedingly variable. Little affected by the cultivation of the country, as it occurs to-day quite as often in the city lawn as in the woodland pasture. In the "poison oak" variety it is a low, large-leaved, shrubby-looking plant, sometimes only a few inches high and resembling a young jack oak; but it blooms and fruits, in such humble guise, quite as freely as when it stands a bush five or six feet high, or as a creeping vine it climbs a hundred feet to the summit of some forest tree, fast clutching the bark of the supporting stem by millions of fibrous insinuating or adhesive rootlets. An unmitigated nuisance, although the number of persons affected by the poisonous quality of the plant would seem to be small. The plant is omnipresent, and cases of poisoning certainly not frequent. Fruit in autumn dry, white, or whitish.

Rhus canadensis Marsh. Sweet-scented Sumac. This occurs probably in the county. It is reported from Delaware and Clayton counties. In foliage it resembles the preceding, but has the fruit of the other species. "Ye shall know them by their fruits."

LEGUMINOSÆ.

Amorpha fruticosa Linn. False Indigo. A shrub five or six feet high, with profuse purple bloom in July and August. Not uncommon along the sandy banks of streams and by the river front.

Robinia pseudacacia Linn. Locust. Black Locust. A commonly planted tree and in not a few places escaped from cultivation, though probably not indigenous. In the last twenty or thirty years the tree has been almost ruined by borers. Fortunately these enemies are just now less injurious and locusts are coming in again. We have no tree of rapid growth which can compare with this for excellence and density of wood. The stems six inches in diameter make the very best of posts.

Gleditschia triacanthos Linn. Honey Locust. Not uncommon in the northern part of the county. Probably to be found in all parts of the wooded region. A magnificent tree well worthy of cultivation. The wood is heavy and hard, admits of a beautiful polish, and is useful for all sorts of purposes. Like the black locust the tree grows rapidly, and is easily cultivated from the seed. A thornless variety may be obtained from nurserymen and is to be preferred. Linnæus is reported to have at first written *Gleditsia*, and so the name in some lists appears; but surely reformed nomenclature does not sanction bad orthography!

Gymnocladus canadensis Lam. Kentucky Coffee Tree. Reported not rare in the eastern part of the county, probably to be found in the wooded districts everywhere. A very handsome ornamental tree of rapid growth and yielding valuable wood. The heart-wood is of a fine brown color, takes an elegant polish, is hard, heavy and durable. For outdoor use, posts, rails, etc., there is nothing better. As an ornamental tree, the soft, abundant foliage commends it in summer, and the curious twigless branches in the leafless season make it attractive by contrast with the winter habits of other arboreous forms of vegetation. The flowers produce comparatively little fruit, and the seeds are with difficulty made to grow, sometimes not until the third year after planting. Propagation is best effected by shoots and root-cuttings. The tree is easily transplanted and has few or no insect enemies, such as borers and the like. "Abundant at Eagle Point."—*Anderson.*

ROSACEÆ.

Prunus americana Marsh. Wild Plum. Not uncommon; forming thickets in all parts of the county, but of late much injured by drought and by cattle. The fruit is excellent, and since the trees are perfectly hardy it is a matter of wonder that the farmers do not attempt the preservation of our wild plums rather than the cultivation of uncertain varieties offered by traveling "tree men." Besides the bloom of the wild plum makes it most desirable as an ornamental tree. A plum thicket in full bloom is worth going miles to see, and the sweetness of its delicate perfume is proverbial.

Prunus chicasa Michx. Chickasaw Plum. Red Plum. A tree less common than the last, the fruit and stone smaller, red, very sweet when ripe. All the good things known of the preceding species are also true of this. Quite abundant near the upper end of Pine Hollow. This will perhaps be called later on *Prunus angustifolia* Marsh.

Prunus virginiana Linn. Choke Cherry. A small tree, not uncommon throughout. Chiefly valuable for purposes of ornament. Like some other shrubs here listed, it sends up shoots from the roots and is liable to form a thicket.

Prunus serotina Ehrh. Wild Cherry. Black Cherry. A beautiful tree, widely distributed; common in all the groves of second-growth visited. Rapid growing, it yet forms a dense, fine-grained wood, most valuable for all purposes where fine finish is desirable. Endures shade well and will prove extremely useful in forest planting.

Physocarpus opulifolius Maxim. Nine-bark. A pretty shrub, common in adjoining counties on rocky banks and probably in Dubuque county, though not noticed by the present author.

Rubus strigosus Michx. Wild Red Raspberry. Widely distributed by birds and not uncommon in waste places.

Rubus occidentalis Linn. Black Raspberry. Occurs in dry places and fields with the last mentioned.

Rubus villosus Aiton. Blackberry. Said to have been formerly very common. All these forms are now largely tramped out by cattle in the overcrowded pastures.

Rosa blanda Aiton. Wild Rose. This is the common wild rose of the Mississippi valley. Frequent in sandy soil and on dry hills everywhere. The flowers are very handsome but "single" and of short duration.

Pyrus coronaria Linn. Crab-apple, Wild Crab, Sweet Crab. Sweet-scented Crab. Not uncommon in thickets along hillsides and by streams, Crab-apple trees deserve protection at the hands of every farmer. When in bloom they are the most beautiful object of the landscape and even the fruit is not without its admirers. It should be planted in corners where it may have full room to send up shoots. A single tree in this way will soon originate the characteristic thicket. Strange to say during these later droughty years, the crab-apple like its congeners has suffered much from pear-blight!

The name given by Linnæus shows that the beauty of the tree 100 years ago did not lack appreciation; *coronaria* means suitable for crowns and garlands.

Cratægus coccinea Linn. Scarlet Haw. Red Haw. White Thorn. Hawthorn. Not uncommon in woodlands throughout the county. Another of our most valuable ornamental trees. Its white flowers yield in beauty to those of the crab-apple only while it has the added advantage of its autumn-gladdening scarlet fruit. The variety *mollis* of Torrey and Gray is more common with us in eastern Iowa. It has downy twigs, blooms earlier and grows to large size. Specimens are often twenty and sometimes thirty feet high.

Cratægus crus-galli Linn. Cockspur. Cockspur-thorn. Not common. One specimen was observed in Peru township, but it doubtless occurs in all parts of the county, along creek and river bottoms. Less desirable than the other thorns, by reason of its spininess. The thorns are stout but slender, sometimes three inches in length. The flowers are showy and profuse but ill-scented. Nevertheless the bush deserves a place on the lawn or by the hedgerow. The species is suggested as a hedge-plant for which it would be excellent, but that in such situations all the hawthorns suffer greatly from apple borers and are consequently disappointing.

Cratægus tomentosa Linn. Thorn-apple. Miss McGee reports this from this county. It is given in Mr. Cameron's list for Delaware county immediately west. It is distinguished from *C. coccinea mollis* by the larger leaves, densely pubescent beneath, serrate and with margined petiole, the flowers small, ill-scented, fruit small and dull red, not scarlet. Anderson reports this form common.

Amelanchier canadensis (Linn) Medic. Shad bush. Service-berry. Juneberry. Common on rocky hillsides everywhere, wherever such localities are still wooded. Seems to prefer southern and western exposures. A handsome bush or small tree; usually ten to fifteen feet high, but sometimes twenty to thirty. The racemes of lovely snowy flowers appearing before the leaves in early spring make this one of the most welcome harbingers of vernal life's return. The species runs into many varieties to the delight of nurserymen. Most forms differ, however, chiefly in foliage. A broad-leaved form growing only six to eight feet high, is not uncommon in eastern Iowa. The small varieties are said to be more productive of fruit. The small, richly-colored berries, ripe in early summer, are in high favor among some people.

Amelanchier spicata (Lam.) Dec. Low June-berry. Prof. Anderson reports this as occurring on rocky places south. Probably rare.

SAXIFRAGACEÆ.

Ribes cynosbati Linn. Prickly Gooseberry. Occurs sparingly in the wooded parts of the county on the sides of the bluffs, on the hills in Cascade township, etc., known by its very prickly fruit.

Ribes floridum L'Her. Wild Black Currant. Rare. In woodlands, especially in rich alluvial soils. A beautiful shrub, well repaying cultivation by its profuse bloom in early summer. The fruit is good for birds only.

Ribes gracile Mx. Prof. Anderson reports this common in the eastern part of the county.

HAMAMELIDACEÆ.

Hamamelis virginiana Linn. Witch-hazel. Winter-bloom. In Dubuque county, found apparently in the driftless areas only. A bush was noticed in Pine Hollow, and Miss McGee reports it common east of Epworth, which would probably bring it into a similar region. The species is very rare in the state. It occurs in the driftless part of Delaware county, but is not, so far as I can now recall, reported from any other station in Iowa. It occurs rarely along the Mississippi river, opposite Muscatine, but not on the Iowa side. The witch-hazel, long famous in books of medicine, is a favorite ornamental plant wherever known. It is hardy in Iowa, a clean, beautiful shrub. Its curious, showy, yellow flowers coming so out of season, in October, when all the leaves are falling, are a perennial surprise. The fruit forms during the succeeding summer, so that flowers and ripe fruit may be found on the twigs at the same time.

CORNACEÆ.

Cornus circinata L'Her. Dogwood. Round-leaf Dogwood. A common shrub in all sorts of soil, forming often the margin of the copse, and conspicuous in the season by its cymes of small white flowers. Later on, the light blue berries form a pleasing contrast to the dying foliage.

Cornus stolonifera Michx. Red-osier Dogwood. Not infrequent along streams. Propagated by runners. This species does not thrive well when transplanted to drier localities, but may well take the place of willow here and there, in a low corner of the premises. The flowers are few and small but the pallid or white berries are attractive in the fall, and the red twigs are showy.

Cornus paniculata L'Her. Panicled Cornel-bush. Common along the river banks and by rocky streams. This is the most attractive of our native species, but does not flourish well in our dry uplands. The cymes of flowers are often profuse and panicled, in June, and later on the white fruit is one of the consolations of autumnal woods.

Cosnus alternifolia L. f. Alternate-leaved Cornel. Prof. Anderson reports this frequent.

CAPRIFOLIACEÆ.

Sambucus canadensis Linn. Elderberry. Elder. Common everywhere, the seeds being distributed widely by birds. Sometimes cultivated in farm-gardens for the sake of the abundant fruit.

Sambucus racemosa Linn. Red Elder. Red berried Elder. Miss McGee reports it from the vicinity of Buena Vista. It ranges across the continent but is chiefly north of us in the Mississippi valley. The plant is more woody than the last named and is further distinguished by its brilliant red fruit in the pyramidal clusters, sometimes *white!* Well worthy of preservation and cultivation.

Viburnum opulus Linn. Cranberry Tree. High Cranberry. Found in the northern part of the county only, along the streams tributary to the Turkey and the Mississippi. This is really the wild phase of our common snowball, and its white flower-clusters show in nature, around the rim, the snowball sterile type. The fruit is bright red and showy, sometimes used instead of cranberries. Certainly a beautiful ornamental shrub.

Viburnum dentatum Linn. Arrow-wood. A small slender tree, not uncommon on low grounds. The fruit is small, purple or dark blue, with grooved seed; otherwise the species resembles the next.

Viburnum lentago Linn. Sheep-berry. Sweet Viburnum. Black Haw. Becoming rare. Formerly common along all streams. A valuable ornamental tree. The white flowers are showy, and the rich black fruit half an inch long is edible.

Viburnum prunifolium Linn. Black Haw. Sheep-berry. Formerly not rare in all eastern Iowa; now almost extinct. Resembles the last species. The fruit is in the two species much the same. The present species is much more common south of us, and is said to be still frequently seen in our southern counties.

Vibarnum pubescens Pursh. Downy-leaved-arrow-wood. Prof. Anderson finds this on the bluffs facing the river.

Lonicera sullivantii Gray. Honeysuckle. Common on rocky bluffs where not too closely pastured. The species is not rare in cultivation and will be useful in covering again the dry rocky cliffs which have been denuded of trees.

Lonicera glauca Hill. Honeysuckle. Resembles the last but occurs more sparingly on rocky hillsides. The flowers are smaller, about a fourth of an inch long, and only the uppermost leaves are connate. Both species are ornamental and useful.

Diervilla trifida Mœnch. Bush-honeysuckle. Not uncommon. Prof. Anderson reports it abundant near Eagle Point.

OLIVACEÆ.

Fraxinus americana Linn. Ash. White Ash. American Ash. Not uncommon in rich and moist woods. One of our finest forest trees, the lumber being of the highest utility wherever lightness and strength are at once desired. The tree is readily propagated from the seed, as hundreds of ash groves in the northwestern part of Iowa abundantly testify. As an ornamental or shade tree the ash is also of the highest rank. Its clean white trunk and dark olivaceous leaves and generally vigorous health make it worthy of our best consideration. It is said that the wood of young trees, second growth, is superior in toughness to the more abundant product of large trees, so that he who plants ash trees may early expect profitable return.

Fraxinus viridis Michx. Swamp Ash. Water Ash. Green Ash. Black Ash. Common on low grounds, especially along the Maquoketa river. A tree of moderate size never attaining the elegance or magnificence of its congener. Nevertheless the green ash is a handsome tree, and valuable alike for shelter and fuel. United States publications write this now *F. lanceolata* Barkh.

THYMELEACEÆ.

Dirca palustris Linn. Leatherwood. Wicopy. Moose-wood. Rare. Once abundant along all the streams of the county. Of no value, save as an ornamental shrub, its exceedingly tough, pliable branches making it an object of curiosity. It presents us, however, with handsome honey-colored flowers in June, followed by oval reddish berries. Refuses to be transplanted and must be raised from seed.

URTICACEÆ.

Ulmus fulva Michx. Slippery Elm. Red Elm. Not uncommon, but less abundant than the following, smaller also and less valuable. The wood is durable and is said to last well for posts. This is now written *U. pubescens* Walter.

Ulmus americana Linn. Elm. White Elm. American Elm. One of our finest trees and happily common. It affects rich soils, especially bottom lands, and there attains great size and splendor. The large trees in Dubuque county, as elsewhere, have been mostly cut away, but young trees are everywhere. This is our very best street tree. No other species gives us, along the streets and highways, such superb effects. Vigorous health, adaptation to all sorts of soils, enabling it to endure almost unlimited abuse, and general utility combine to make this a most valuable tree.

Ulmus racemosa Thomas. Cork Elm. Hickory Elm. Rare in the northwestern part of the county. Though not so common the rock elm rivals the last in nearly all commendable qualities. The wood is said to be finer grained, tougher, and for some purposes for which elm is used, more desirable; may even take the place of hickory in tool and carriage construction. It is, therefore, in the highest degree worthy our protection and cultivation.

Celtis occidentalis Linn. Hackberry. Not uncommon in low grounds, especially along streams. The trees do not attain large size, but are rapid growers and make excellent fuel. As a shade tree the soft, pale green foliage recommends it in contrast to trees of other species. The red berries are edible, but of small value, save as food for birds.

Platanus occidentalis Linn. Sycamore. Buttonball. Buttonwood. Plane Tree. Rare. Once common along the Maquoketa, between Cascade and Worthington, also along the Mississippi river front. A handsome tree with large leaves and often with snow-white branches. One of the largest of the trees found in the Mississippi valley, sometimes 75–100 feet high and ten or twelve feet in diameter. Does not flourish well on high grounds.

JUGLANDACEÆ.

Juglans cinerea Linn. White Walnut. Butternut. Reported once common by all the streams of the county, now comparatively rare, represented by comparatively small trees. A very valuable species, the wood beautiful for cabinet-work and interior finish. Easily cultivated from the seeds and susceptible of transplanting again and again, when raised in nurseries. Flourishes best in bottom lands and in the neighborhood of streams.

Juglans nigra Linn. Walnut. Black Walnut. Small trees of this species are not uncommon in all the wooded districts of the county. Large trees are said to have been at one time very common. This is one of our finest, most beautiful and in every way most valuable forest trees. It will sound strange to some of our younger farmers when they are told that black walnut trees were once so common in Iowa that they were indiscriminately cut down to make rails to fence the land on which they stood. If standing now such trees would make their owner wealthy. The black walnut, if properly cared for, grows very rapidly. The tree bears fruit in eight or ten years and in as many more will show a trunk twelve to sixteen inches in diameter. In from twenty to forty years under favorable circumstances, good soil, freedom from abuse by cattle, the trees will furnish fine saw-logs. There is many an odd strip of land in Iowa that might be very profitably set to raising walnuts. Better still, there are in our surviving second growth woods, hundreds of young trees which if cared for will reproduce themselves and will in twenty years more be very valuable property. For planting, walnuts should be gathered in autumn, mixed with sand and piled up in heaps, where not subjected to the depredation of thievish animals, to freeze. In spring, plant in rows and cover only an inch or two, and you will have young walnuts to spare. The young trees should be set out when small, unless subject to nursery treatment, when they can be handled safely even when six or eight feet high. The nurseryman transplants early and often and so modifies the roots. In any event the trees should be planted where they can be cultivated until the ground is shaded, and must be subsequently watched and thinned out as they become large.

Carya alba Nutt. Shell-bark Hickory. Hickory. Common in upland woods. Large trees are rare. Another most valuable tree. The tough white wood is in great demand for carriage building, for construction of agricultural implements, tool-handles, etc.; the waste wood as fuel has long been everywhere famous, the nuts are always salable, while as an ornamental tree it has never been half appreciated. It has the advantage, too, of ability to grow on poor soil. It thrives all over the loess and stony hills of northwest Dubuque county. For cultivation it must be raised from seed—treated as the walnut—as it does not well endure transplanting from the forest. By late writers all hickories are called *Hicoria* Rafinesque, because it is thought that that rather unreliable author intended to apply this or a similar name to the noble group of trees which Nuttall later defined as making up the genus *Carya*. The present species is by these authors written *Hicoria ovata* (Mill.) Britt.,—*ovata* being an early specific name.

Carya amara Nutt. Bitternut. Pig Nut. White Hickory. Common, with about the same range as the last. A small, graceful tree, less valuable by far than the last, but making excellent fuel and well worth a place in our list of ornamental trees. This species by recent authors is written *Hicoria minima* Marsh.) Britt.

CUPULIFERÆ.

Betula papyrifera Marsh. Paper Birch. White Birch. Common on rocky hillsides in the northwest part of the county as in Pine Hollow. A beautiful ornamental tree, its snowy stem shines through the leaves, unique among all the trees of the lawn or hillside. Planted with evergreens for a background, the white stems make a very pleasing contrast in winter.

Betula nigra Linn. Birch. Black Birch. River Birch. Red Birch. Common by the river side, along the Mississippi, and more rarely by the Maquoketa. A small tree of no great value except for fuel. Should, however, have a place among our trees planted for ornament. It has a graceful form, is hardy and healthy, while its glistening leaves and fluttering bark make it very attractive.

Corylus americana Walt. Hazelnut. Common everywhere where not exterminated by processes of cultivation. A valuable bush alike for its fruit and as a nurse for less rugged species—the forerunner of the forest.

Ostrya virginica Willd. Ironwood. Hop Tree. Horn-beam. Common on wooded hillsides. A small, slow-growing tree, the wood very hard and valuable for the manufacture of tool handles and similar utensils.

Carpinus caroliniana Walt. Blue Beech. Water Beech. Not uncommon in little groves or clusters close down at the water's edge along streams everywhere. A small tree, very handsome in its place. The wood useful for the same purposes as the last named species. Both these trees further south attain much greater dimensions.

Quercus alba Linn. White Oak. Common throughout, especially on clay ridges. An invaluable tree. Splendid specimens recently stood in section 5 of Liberty township, just overlooking Pine Hollow, but most of them were cut away a few years since to make lumber for bridges and the like. The oak is of slow growth, but after all will more and more repay protection. It occupies soil of small value for anything else, as in the case mentioned, and in fact soon comes to utility. By judicious thinning of the white oak grove, splendid trees at length stand upon the earth. This is also a beautiful ornamental tree, whether for lawn or park. The clean stem and pale green leaves are very beautiful, while in the autumn the large, handsomely ornate fruit and the leaves glowing beneath the touch of frost, possess a charm that must make irresistible appeal to every lover of the beautiful in nature.

Quercus macrocarpa Michx. Bur Oak. Scrub Oak. Very common, especially on exposed points, in hard situations, on sandy flats, and rocky knolls. In the last named habitat the tree is apt to be gnarled and stunted, unattractive; hence called scrub oak. The species endures all sorts of adverse conditions, but under these is a tree of very slow growth. Under better circumstances bur oaks come on quite rapidly and make excellent timber. Nothing equals them for posts, and the lumber made from bur oak logs is second to white oak only, in excellent qualities. The tree grows readily from the seed, but is not easily transplanted.

Quercus rubra Linn. Red Oak. Common everywhere in wooded districts. Grows to large size rapidly and furnishes the familiar coarse-grained wood useful to the builder. Some fine specimens are still standing on the clay ridges of the northwest part of the county.

Quercus coccinea Wang. Scarlet Oak. Black Oak. Jack Oak. Common everywhere. A small tree with shining leaves and small fruit, holding its leaves sometimes late into the winter. The most common species in the county as in eastern Iowa. Often occupying almost exclusively a sandy hill entire; especially common in groves remote from the main body of the forest. This seems to be with us a comparatively short-lived tree. All oaks in this country show a certain deterioration with age. The wood of the white oak, for instance is at its best when 75 or 100 years old, and continues at its maximum of excellence for perhaps 100 years longer, probably less; after that the wood deteriorates, becomes brash and in every way less desirable. Trees of the scarlet oak reach a much earlier maturity and seem to die a natural death at 40 to 70 years. Exact data along these lines are much to be desired. *Q. coccinea var. tinctoria* Gray differs in many particulars and is some places more common than the type. It may be known by its generally duller foliage, changing in autumn to brown or orange, the inner bark orange or yellowish. This is more properly called yellow oak. A better tree than *Q. coccinea.* The variety is now written by some authors *Q. velutina* Lam.

SALICACEÆ.

Salix nigra Marsh. Black Willow. Common along streams and sometimes planted. A small tree of little value save perhaps to form wind-breaks and, by reason of rapid growth, to furnish quick supply of fuel.

Salix discolor Muhl. Pussy Willow. A low shrub along streams, noted for its early flowering.

Salix humilis Marsh. Prairie Willow. On dry uplands. Not very common. A shrubby species of no special value.

Salix tristis Aiton. Dwarf Willow. Gray Willow. Common in thin woods, on the borders of thickets etc., everywhere in poor soils.

Populus tremuloides Michx. American Aspen. Quaking Asp. Common on low grounds throughout the wooded part of the county. With us in Iowa a small tree; further east it attains considerable size, sometimes "100 feet high." Chiefly valuable as a nurse for trees of other species. The seeds are distributed by the wind, germinate quickly and the young plants grow rapidly in exposed situations. For these reasons this tree is of the highest importance in reforestation especially on poor soils, in steep places where it may be used to prevent the washing of the soil, to hold the field until better species get a start.

Populus grandidentata Michx. Poplar. Quaking Asp. Aspen. Common, especially on hillsides in second-growth groves. A slender short-lived tree, noted for rapid growth and useful as a support for trees of other species. The long slender poles are useful to the farmer and are often used as rafters in barns and sheds. The wood is valuable as light or summer fuel.

Populus monilifera Aiton. Cottonwood. Common everywhere and in days gone by commonly planted on the prairie farms and by the highways. Valuable as a shelter tree, also for fuel. In our rich prairie soils it grows with wonderful rapidity; trees thirty or forty years old are sometimes two or three feet in diameter. This, box elder, and soft or white maple are the trees that have made possible the occupation of the prairies of Iowa. This is now written *P. deltoidea* Marsh.

MONOCOTYLEDONES.

LILIACEÆ.

Smilax hispida Muhl. Greenbrier. A common, dark green, prickly vine, sometimes called sarsaparilla. *Smilax rotundifolia*, also occurs. Not uncommon.

GYMNOSPERMÆ.

CONIFERÆ.

Pinus strobus Linn. Pine. White Pine. Rare. A few trees in Pine Hollow, Liberty township. The most valuable tree in the world! There is no lumber for the homes of men that can take the place of pine, and while in other regions other species supplant this, yet none has ever equaled in quantity or wide utility the white pine of northeastern North America. The tree attains great size, and rapidly reproduces itself on soils not destroyed by fire. Second-growth pine, on abandoned farm lands, now furnishes to New England a most important industry. No tree is more handsome on the lawn, no forest better than white pine affords shelter from winter's cold or summer's heat, no trees give in lumber speedier return. White pine grows naturally in our county; it will, under cultivation, prove a thoroughly satisfactory plant.

Juniperus virginiana Linn. Cedar. Red Cedar. Not uncommon along the rocky hills and bluffs. Widely planted as an ornamental tree, for which it is chiefly valuable. It undergoes indefinite cl ipping and shearing, and makes pretty lawn hedges. The wood is exceedingly durable, and where it can be obtained in quantity is very serviceable for posts.

Juniperus communis Linn. This is a low shrub, evergreen, with prickly or sharp-pointed leaves; probably occurs in this county. *Taxus canadensis*, American yew, is also to be mentioned here.

It will be seen on reviewing our list that there is hardly a species native to Dubuque county, which does not possess in greater or less degree economic value. These woody plants constitute part of the natural wealth of the county, just as surely as the lead found in the crevices of the rocks. The fact that these particular species flourish here by nature is, as has been already urged, an index to the possibility of forest development, of arboriculture and horticulture, of farm building and home building in eastern Iowa, once science gets a hearing and its teachings reach and influence all the intelligent people that make up our land-owning population. When that time comes Dubuque county will be fairest of our river counties, part and parcel of the most beautiful valley in the civilized world.